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MADE IN SINGAPORE

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In this paper, we characterize the position of Singapore in global value chains and identify Singapore's key upstream and downstream trade partners. We trace how the position of Singapore in global value chains has changed in the past two decades: whether it has moved upstream or downstream, how involved it is in global value chains, how its trend compares with the other major Asian exporters (China, Japan, Korea, Taiwan and Hong Kong), and which key sectors of Singapore play a major role in these global trade networks.

Keywords: Global value chain; gross export decomposition; upstream/downstream trade partners; GVC participation; GVC position.

JEL Classification: F14, F15

1. Introduction

International trade has played a dominant role in the growth of Singapore's economy. In recent years, Singapore's external demand (net exports) has typically accounted for more than 90% of its income growth (Ministry of Trade and Industry, 2011–2018). Its key trade partners include China, East and Southeast Asian countries, the EU, the US, and Australia.

This is against a backdrop where production processes are increasingly fragmented, with parts and components now regularly sourced from several countries (trade in intermediate inputs), and services procured across borders (trade in tasks). A great deal of evidence suggests that global production sharing is on the rise, as documented by Campa and Goldberg (1997), Yeats (2001), Hummels *et al.* (2001), and Johnson and Noguera (2012). This is made possible in large part by falling costs of transportation and communication technology, and lower policy barriers due to multilateral/preferential trade agreements.

In this paper, we characterize the position of Singapore in global value chains and identify Singapore's key upstream and downstream trade partners. We trace how the

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position of Singapore in global value chains has changed in the past two decades: whether it has moved upstream or downstream, how involved it is in global value chains, how its trend compares with the other major Asian exporters (China, Japan, Korea, Taiwan and Hong Kong), and which key sectors of Singapore play a major role in these global trade networks. We also evaluate the importance of the CPTPP free trade agreement to Singapore in terms of how critical the signatories are in Singapore's global production network, and the impact if China and/or the US were part of the agreement.

Toward these goals, we use the OECD-WTO Trade in Value-Added (TiVA) database. The 2016 edition of the TiVA table traces the inter-country input–output (ICIO) linkages for 63 economies (and the rest of the world) in 34 industrial sectors (based on ISIC Rev.3) for the years 1995–2011. The majority of our analysis is based on the 2016 edition. To understand recent developments since 2011, we also supplement with the 2018 edition of the TiVA table that covers the period 2005–2015. Comparison across periods before and after 2011 needs to be exercised with caution because the classification of economies and sectors differs between editions.[1]

We apply the methods of Koopman *et al.* (2014) (hereafter KWW) and Borin and Mancini (2017) (hereafter BM). The former study provides a useful accounting framework to decompose a country's aggregate gross exports into domestic value-added (DVA), foreign value-added (FVA) and pure double-counting components. The latter study further provides accounting frameworks for such decomposition at the bilateral export and sector levels. We review the related literature in Section 1.1 and elaborate on the methods in Section 2.

To the best of our knowledge, there have been no systematic studies analyzing the value-added trade of Singapore and its participation in global value chains. Singapore is typically included in large group studies without much mention (De Backer and Miroudot, 2014; Gereffi, 2014). Chen and Shao (2017), in their discussion of the challenges faced by Singapore in the new globalization era, mention Singapore's low participation in Southeast Asian production networks and the low value-added ratio of its gross exports. In this paper, we provide a comprehensive study of Singapore's participation in global value chains, by applying the most current framework in the literature to trace the value-added contents of Singapore's gross trade flows and to present summary measures of the economy's integration with the international production network.

1.1. *Literature on global value chains*

In the last three decades, production processes have become increasingly fragmented in stages yet integrated across countries. Following the classic case study of Apple iPod by Dedrick *et al.* (2010), research has analyzed the value chains of alternative products such as smartphones (Ali-Yrkkö *et al.*, 2011) or of a larger set of final manufactured products (Timmer *et al.*, 2014). Although the extent of fragmentation may vary across products, it is undeniable that intermediate inputs nowadays travel across multiple countries in several production stages before reaching their final destination. According to

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[1] The later edition includes one more individual economy entity and 36 sectors (based on ISIC Rev.4). See Tables A.1 and A.2 for the list of economies and sectors. More details are provided at http://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm. Tables are available from https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm.

Timmer *et al.* (2014), the foreign value-added share in output increased from 28% to 34% during 1995–2008 for 85% of the 560 product chains they studied. Along with this fragmentation trend comes challenges for standard trade statistics to truly represent demand and supply linkages across economies. Since intermediate inputs cross international borders multiple times, the traditional trade statistics repeatedly double-count the same value added. This leads to a discrepancy between gross export flows and value-added exports (Johnson, 2014). Such divergence can fundamentally affect quantitative analysis and policy implications.

In response, datasets known as Inter-Country Input–output (ICIO) tables have been developed. These tables link harmonized national input–output tables with bilateral trade data in goods and services by end-use category. At present, there are six major sources of data on global input-output linkages. These are the Global Trade Analysis Project (GTAP) (Aguiar *et al.*, 2016), World Input-output Database (WIOD) (Timmer *et al.*, 2015), OECD-WTO TiVA Database, Eora Multi-Region Input-output Table (MRIO), IDE-JETRO Asian Input-output Table, and EXIOBASE Multi-Regional Environmentally Extended Supply and Use / Input Output database (MR EE SUT/IOT).[2] While country-wise input-output tables are available at disaggregated levels and for an extended period, most global input-output tables have been constructed at a level of aggregation higher than available in primary sources, and currently only cover the post-1990 period (with some providing tables for only benchmark years) (Johnson, 2018). Despite their shortcomings, these global input-output databases are currently the best resources to measure value-added trade and GVC indicators. For this paper, we choose to work with the OECD-WTO TiVA Database for its inclusion of Singapore as a separate entity, its detailed country and sector coverage, and its wide applications in the literature.[3] The methodology and assumptions underlying the construction of the TiVA tables are provided in OECD-WTO (2012).

Based on the ICIO tables, new methods have been developed to account for gross trade flows. Koopman *et al.* (2014) proposed a decomposition framework of aggregate gross exports by the source and destination of embedded value added. The accounting framework decomposes a country's aggregate gross exports into nine components (grouped into domestic value-added, foreign value-added, and purely double-counted terms). See also Los *et al.* (2016) for an alternative method based on "hypothetical extraction". The KWW framework, being constructed for national aggregate exports, is further generalized by the literature (Wang *et al.*, 2013) to bilateral exports and sector-level trade. Nagengast and Stehrer (2016) highlighted the important distinction between source- and sink-based approaches in accounting for value added in gross bilateral trade flows: the former from the perspective of the country where the value added originates and the latter from the perspective of the country that ultimately absorbs the value added in final demand. Most recently, Borin and Mancini (2017) refined the KWW decomposition using the two distinct perspectives of Nagengast and Stehrer (2016) while correcting some value-added

[2] GTAP: www.gtap.agecon.purdue.edu. WIOD: www.wiod.org. OECD-WTO TiVA: oe.cd/tiva. Eora MRIO: worldmrio.com. IDE-JETRO: www.ide.go.jp/English/Data/Io. EXIOBASE: www.exiobase.eu.

[3] WIOD and EXIOBASE do not include Singapore as a separate entity; IDE-JETRO provides coverage for only major Asian countries and the US as separate entities; GTAP provides data for limited reference years (2004, 2007, 2011, 2014); and Eora has less disaggregated coverage of manufacturing sectors than TiVA does.

assignments in the original KWW decomposition. In Section 2, we review the methods that have been developed in the recent literature to trace the value-added trade across countries. The different components of value-added trade form the basis of our analysis.

In parallel, the literature has developed several measures of a country's participation in the global production chains. The seminal paper by Hummels *et al.* (2001) introduced the vertical specialization (VS) index, where the extent of a country's participation in vertical specialization is measured by the imported content in the country's exports. The same study also proposed an alternative index (VS1) that measures the extent of a country's exports used as inputs in another country's production of exports. Subsequent works have utilized ICIO tables and proposed further GVC-related indicators. These include Koopman *et al.* (2010), Daudin *et al.* (2011), Johnson and Noguera (2012), and Los *et al.* (2015). In particular, Daudin *et al.* (2011) proposed a measure (VS1*) that further distinguishes the part of VS1 that returns to the country of origin as final goods. Johnson and Noguera (2012), in contrast, focused on value-added exports, to measure a country's domestic value-added absorbed abroad via final or intermediate goods exports. They then used the ratio of value-added exports to gross exports ("VAX ratio") to measure a country's value-added content of trade. Finally, Borin and Mancini (2017), using their refined gross export decomposition, provided a measure of value added that crosses national borders more than once and hence a new way to calculate the share of GVC-related trade in a country's gross exports. In Section 4, we analyze the extent of GVC participation by Singapore based on some of the above indicators, using the gross export decomposition carried out in Section 2.

Relatedly, some studies have attempted to measure the relative position of a country or sector in the global production networks. Antràs *et al.* (2012) and Fally (2012) suggested two equivalent indices that measure the upstreamness of a sector. A sector (country) is defined as being relatively more upstream in the production chain if it is more distant from final demand (or if it sells a disproportionate share of outputs to relatively upstream industries). On the other hand, Miller and Temurshoev (2017) and Fally (2012) proposed two equivalent down-streamness indices, where a sector (country) is considered to be relatively more downstream in the value chain if it is located farther away from its source of value added (or if it buys a disproportionate share of inputs from relatively downstream industries). As noted by Antràs and Chor (2018), however, the upstreamness and downstreamness measures tend to be positively correlated (i.e., sectors that are considered more upstream by the upstreamness measure also tend to be more downstream by the downstreamness measure). The same pattern is observed in our analysis below when applying these measures proposed by the literature. In Section 5.3, we propose measures to characterize the position of a country in the global value chains. We demonstrate how the proposed formula can be used to provide informative measures of the GVC positions of trading economies. In Section 6, we extend the analysis to the sector level and draw comparisons across sectors in terms of their GVC participation and position.

2. Gross Export Decomposition Framework

As highlighted by Nagengast and Stehrer (2016), decomposition of a country's bilateral gross exports (instead of aggregate gross exports as in KWW) requires one to clearly identify the

bilateral export flow to which a value-added component is assigned, and the other bilateral export flows where the component is labeled as purely double-counted (DC) from the world GDP perspective, if the value-added component crosses country borders several times. The assignment rule depends on whether one takes the source-based or the sink-based approach.

In the source-based approach, a domestic value-added (DVA) component is attached to the bilateral gross exports the first time the value-added component leaves the country of origin (and is labeled as double-counted for the subsequent times it leaves the country of origin). On the other hand, the sink-based approach attaches a domestic value-added component to the bilateral gross exports the last time the value-added component leaves the country of origin. For example, if a value-added component originates from Singapore, is shipped to China, returns to Singapore, and is further shipped to Malaysia before reaching the US as final destination, the Singaporean value-added would be considered by the source-based approach to be DVA in Singapore's gross exports to China and domestic double-counted (DDC) in Singapore's gross exports to Malaysia. The assignment is reversed if one adopts the sink-based approach.

In parallel, in the source-based approach, a foreign value-added component is attached to the bilateral gross exports the first time the value-added component is re-exported (and is labeled as double-counted for the subsequent times it crosses other national borders). On the other hand, the sink-based approach attaches a foreign value-added component to the bilateral gross exports the last time the value-added component is re-exported. Using the above example, the Singaporean value-added component would be considered by the source-based approach to be FVA in China's gross exports to Singapore and foreign double-counted (FDC) in Malaysia's gross exports to the US. In contrast, it would be labeled by the sink-based approach to be FVA in Malaysia's gross exports to the US, but FDC in China's gross exports to Singapore.

The choice obviously will affect the relative importance of value-added and double-counted components (domestic or foreign) in a country's bilateral exports (e.g., Singapore to China, or Singapore to Malaysia). It will also affect the proportion of FVA versus FDC (although not DVA versus DDC) of a country's aggregate exports. For example, a more upstream exporting country may be assigned another country's VA as FVA in its gross exports more often in the source-based approach and less often in the sink-based approach. The two approaches are equivalent only at the world export level (as in either approach, a VA is only counted once in a certain trade flow and considered double-counted in all other trade flows). Which approach is more appropriate depends on the application at hand. We justify the alternative choices below when we present the various characterizations of Singapore's participation in global value chains.

We repeat the BM decomposition framework below for easy reference. Let there be N countries and G sectors. Let $\mathbf{Y}_{sr}$ indicate the demand vector of final goods produced in country s and consumed in country r (of dimension $G \times 1$), $\mathbf{A}$ the global matrix of input coefficients (of dimension $NG \times NG$), $\mathbf{B} \equiv (\mathbf{I} - \mathbf{A})^{-1}$ the global Leontief inverse matrix, $\mathbf{V}_s$ the value-added shares embedded in each unit of gross output produced by country s (of dimension $1 \times G$), $\mathbf{E}_{sr}$ the vector of bilateral exports from country s to country r (of dimension $G \times 1$), and $\mathbf{u}_G$ a $1 \times G$ unit row vector.

2.1. *Sink-based decomposition*

The sink-based approach decomposes the bilateral exports from country s to country r into domestic value-added (Components 1 to 5), domestic double-counted (Component 6), foreign value-added (Components 7 to 9b), and foreign double-counted (9c to 9d) as follows:

$$
\begin{aligned}
\mathbf{u}_G \mathbf{E}_{sr} = \ & \overset{\mathbf{1}}{\mathbf{V}_s \mathbf{B}_{ss} \mathbf{Y}_{sr}} \\
+ \ & \mathbf{V}_s \mathbf{B}_{ss} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \left[\overset{\mathbf{2a}}{\mathbf{Y}_{rr}} + \overset{\mathbf{2b}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \widehat{\mathbf{B}}_{jr}^{\not{r}} \mathbf{Y}_{rr}} + \overset{\mathbf{2c}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \sum_{k \neq s,r}^{N} \widehat{\mathbf{B}}_{jk}^{\not{r}} \mathbf{Y}_{kk}} \right] \\
+ \ & \mathbf{V}_s \mathbf{B}_{ss} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \left[\overset{\mathbf{3a}}{\sum_{j \neq s,r}^{N} \mathbf{Y}_{rj}} + \overset{\mathbf{3b}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \sum_{l \neq s,r}^{N} \widehat{\mathbf{B}}_{jr}^{\not{r}} \mathbf{Y}_{rl}} \right. \\
& \left. + \overset{\mathbf{3c}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \sum_{k \neq s,r}^{N} \widehat{\mathbf{B}}_{jk}^{\not{r}} \mathbf{Y}_{kr}} + \overset{\mathbf{3d}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \sum_{k \neq s,r}^{N} \sum_{l \neq s,r}^{N} \widehat{\mathbf{B}}_{jk}^{\not{r}} \mathbf{Y}_{kl}} \right] \\
+ \ & \mathbf{V}_s \mathbf{B}_{ss} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \left[\overset{\mathbf{4a}}{\mathbf{Y}_{rs}} + \overset{\mathbf{4b}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \widehat{\mathbf{B}}_{jr}^{\not{r}} \mathbf{Y}_{rs}} + \overset{\mathbf{4c}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \sum_{k \neq s,r}^{N} \widehat{\mathbf{B}}_{jk}^{\not{r}} \mathbf{Y}_{ks}} \right] \\
+ \ & \mathbf{V}_s \mathbf{B}_{ss} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \overset{\mathbf{5}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \widehat{\mathbf{B}}_{js}^{\not{r}} \mathbf{Y}_{ss}} \\
+ \ & \mathbf{V}_s \mathbf{B}_{ss} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \overset{\mathbf{6}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} \widehat{\mathbf{B}}_{js}^{\not{r}} \mathbf{E}_{s*}} \\
+ \ & \overset{\mathbf{7}}{\sum_{t \neq s}^{N} \mathbf{V}_t \mathbf{B}_{ts} \mathbf{Y}_{sr}} + \overset{\mathbf{8}}{\sum_{t \neq s}^{N} \mathbf{V}_t \mathbf{B}_{ts} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \mathbf{Y}_{rr}} \\
+ \ & \mathbf{V}_r \mathbf{B}_{rs} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \left[\overset{\mathbf{9a}}{\sum_{j \neq r}^{N} \mathbf{Y}_{rj}} + \overset{\mathbf{9b}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} (\mathbf{I} - \mathbf{A}_{jj})^{-1} \mathbf{Y}_{jj}} \right] \\
+ \ & \overset{\mathbf{9c}}{\sum_{t \neq s,r}^{N} \mathbf{V}_t \mathbf{B}_{ts} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \mathbf{E}_{r*}} \\
+ \ & \mathbf{V}_r \mathbf{B}_{rs} \mathbf{A}_{sr} (\mathbf{I} - \mathbf{A}_{rr})^{-1} \overset{\mathbf{9d}}{\sum_{j \neq r}^{N} \mathbf{A}_{rj} (\mathbf{I} - \mathbf{A}_{jj})^{-1} \mathbf{E}_{j*}}, \quad (1)
\end{aligned}
$$

where (i) $\mathbf{B}_{ts}$ is the country-t to country-s section in the global Leontief matrix $\mathbf{B}$, which corresponds to the total input requirement from each sector of country t to produce a unit of final demand in each sector of country s, (ii) $\mathbf{A}_{sr}$ is the country-s to country-r section in the inter-country input coefficient matrix $\mathbf{A}$, which corresponds to the direct input requirement from each sector of country s to produce a unit of gross output in each sector of country r,

(iii) $\mathbf{E}_{s*}$ is the aggregate export vector of country s, and (iv) $\hat{\mathbf{B}}^{\not{s}} \equiv (I - \mathbf{A}^{\not{s}})^{-1}$ is the Leontief inverse matrix derived from the input coefficient matrix $\mathbf{A}^{\not{s}}$, which excludes the input of country s used in other countries:

$$\mathbf{A}^{\not{s}} = \begin{bmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & \cdots & \mathbf{A}_{1s} & \cdots & \mathbf{A}_{1N} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{A}_{ss} & \cdots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \mathbf{A}_{N1} & \mathbf{A}_{N2} & \cdots & \mathbf{A}_{Ns} & \cdots & \mathbf{A}_{NN} \end{bmatrix}.$$

Table 1 provides a summary of the interpretations of each term in Equation (1). Using the example introduced at the beginning of the section, by the sink-based approach, the gross exports of Singapore to China consist of only double-counted domestic content (Component 6), while the gross exports of China to Singapore consist of Chinese DVA (Component 2c or 3d) and double-counted foreign content contributed by Singapore (Component 9d). The gross exports of Singapore to Malaysia, in turn, consist of the Singaporean DVA (Component 2c or 3a) and the double-counted foreign content contributed by China (Component 9c). Finally, the gross exports of Malaysia to the US include Malaysian DVA (Component 1 or 2a) and FVA by China and Singapore (Component 7 or 8).

   Given the sink-based approach's focus on the last time a DVA leaves its country of origin or the last time an FVA is re-exported, it allows for all possible backward linkages, as captured by the use of the global Leontief matrix $\mathbf{B}_{ts}$, pre-multiplied by the value-added share vector $\mathbf{V}_t$. The accounting also ensures that a foreign content is considered as FVA in the gross exports (from s to r) under study, only if it is not re-exported by third countries subsequently (as seen in Expressions 7–9b). Similarly, a domestic content is counted toward DVA only if it is not subsequently re-imported and leaves the country of origin s again (as facilitated by the use of the restricted Leontief matrix $\hat{\mathbf{B}}^{\not{s}}$ in Components 2–5).

   Finally, note that the sum of Equation (1) across importing countries r and across sub-components (2a–2c, 3a–3d, 4a–4c, 9a–9d) corresponds to the KWW decomposition of a country's aggregate gross exports. For example, the KWW component (1) equals $\mathbf{V}_s \sum_{r \neq s} \mathbf{B}_{ss} \mathbf{Y}_{sr}$ (DVA in direct final goods exports). The remaining KWW components are: (2) DVA in intermediate exports absorbed by direct importers, (3) DVA in intermediates re-exported to third countries, (3) DVA in intermediate exports that returns home via final goods imports, (5) DVA in intermediates that returns home via intermediate imports, (6) double-counted intermediate exports originally produced at home, (7) FVA in final goods exports, (8) FVA in intermediate goods exports, and (9) double-counted intermediate exports originally produced abroad.

   Thus, the aggregate and bilateral decompositions of KWW and BM are consistent algebraically, but with some caveats. First, the assignments of DVA absorbed by the direct importer (Component 2) and by third countries (Component 3) in KWW are not exact, since the BM decomposition indicates that Component 2c is absorbed by third countries while 3c is absorbed by the bilateral importer. Second, Components 9a–9b are considered part of double-counted foreign contents by KWW, whereas they are counted as FVA in BM that originates from the bilateral importer.

Table 1. Decomposition of Gross Exports by the Sink-Based Approach

Gross exports from country s to r	DVA		(1) in direct final goods exports $\mathbf{Y}_{sr}$
		in intermediate goods exports $\mathbf{A}_{sr}$ *absorbed by direct importer r*	(2a) as local final goods $\mathbf{Y}_{rr}$ (2b) as local final goods but only after additional processing stages abroad (3c) as final goods from third countries $\mathbf{Y}_{kr}$
		in intermediate goods exports $\mathbf{A}_{sr}$ *absorbed by third countries*	(2c) as local final goods $\mathbf{Y}_{kk}$ (3a) as final goods from direct importer $\mathbf{Y}_{rj}$ (3b) as final goods from direct importer $\mathbf{Y}_{rl}$ but only after further processing stages abroad (3d) as final goods from other third countries $\mathbf{Y}_{kl}$
		in intermediate goods exports $\mathbf{A}_{sr}$ *absorbed at home*	(4a) as final goods of the bilateral importer $\mathbf{Y}_{rs}$ (4b) as final goods of the bilateral importer $\mathbf{Y}_{rs}$ but only after additional processing stages abroad (4c) as final goods of a third country $\mathbf{Y}_{ks}$ (5) as domestic final goods $\mathbf{Y}_{ss}$
	FVA, $\mathbf{V}_{t\neq s}$		(7) in exports of final goods $\mathbf{Y}_{sr}$ (8) in exports of intermediate goods $\mathbf{A}_{sr}$ directly absorbed by the importing country $\mathbf{Y}_{rr}$
	FVA by direct importer r, $\mathbf{V}_r$	in intermediate exports $\mathbf{A}_{sr}$, re-exported by r directly to the country of final absorption	(9a) via final goods exports $\mathbf{Y}_{rj}$ (9b) via intermediate exports $\mathbf{A}_{rj}$
	purely double-counted components		(6) of domestic content (9c–9d) of foreign content

2.2. *Source-based decomposition*

The source-based approach similarly decomposes the bilateral exports from country *s* to country *r* into domestic value-added (Components 1* to 5*), domestic double-counted (Component 6*), foreign value-added (Components 7* to 9b*), and foreign double-counted (9c* to 9d*), as follows:

$$
\begin{aligned}
\mathbf{u}_G\mathbf{E}_{sr} =\ & \overset{\mathbf{1a*}}{\mathbf{V}_s(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{Y}_{sr}} \\
+\ & \mathbf{V}_s(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\left[\overset{\mathbf{1b*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\mathbf{B}_{js}\mathbf{Y}_{sr}}+\overset{\mathbf{1c*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\sum_{k\neq s,r}^{N}\mathbf{B}_{js}\mathbf{Y}_{sk}}\right] \\
+\ & \mathbf{V}_s(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\left[\overset{\mathbf{2a*}}{\mathbf{Y}_{rr}}+\overset{\mathbf{2b*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\mathbf{B}_{jr}\mathbf{Y}_{rr}}+\overset{\mathbf{2c*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\sum_{k\neq s,r}^{N}\mathbf{B}_{jk}\mathbf{Y}_{kk}}\right] \\
+\ & \mathbf{V}_s(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\left[\overset{\mathbf{3a*}}{\sum_{j\neq s,r}^{N}\mathbf{Y}_{rj}}+\overset{\mathbf{3b*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\sum_{l\neq s,r}^{N}\mathbf{B}_{jr}\mathbf{Y}_{rl}}\right. \\
& \left.+\overset{\mathbf{3c*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\sum_{k\neq s,r}^{N}\mathbf{B}_{jk}\mathbf{Y}_{kr}}+\overset{\mathbf{3d*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\sum_{k\neq s,r,l\neq s,r}^{N}\sum^{N}\mathbf{B}_{jk}\mathbf{Y}_{kl}}\right] \\
+\ & \mathbf{V}_s(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\left[\overset{\mathbf{4a*}}{\mathbf{Y}_{rs}}+\overset{\mathbf{4b*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\mathbf{B}_{jr}\mathbf{Y}_{rs}}+\overset{\mathbf{4c*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\sum_{k\neq s,r}^{N}\mathbf{B}_{jk}\mathbf{Y}_{ks}}\right] \\
+\ & \mathbf{V}_s(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\overset{\mathbf{5*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\mathbf{B}_{js}\mathbf{Y}_{ss}} \\
+\ & \mathbf{V}_s(\mathbf{I}-\mathbf{A}_{ss})^{-1}\overset{\mathbf{6*}}{\sum_{t\neq s}^{N}\mathbf{A}_{st}\mathbf{B}_{ts}\mathbf{E}_{sr}} \\
+\ & \sum_{t\neq s}^{N}\mathbf{V}_t(\mathbf{I}-\mathbf{A}_{tt})^{-1}\mathbf{A}_{ts}(\mathbf{I}-\mathbf{A}_{ss})^{-1}\left[\overset{\mathbf{7*}}{\mathbf{Y}_{sr}}+\overset{\mathbf{8*}}{\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\mathbf{Y}_{rr}}\right] \\
+\ & \sum_{t\neq s}^{N}\mathbf{V}_t(\mathbf{I}-\mathbf{A}_{tt})^{-1}\mathbf{A}_{ts}(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\overset{\mathbf{9a*}}{\sum_{j\neq r}^{N}\mathbf{Y}_{rj}} \\
+\ & \sum_{t\neq s}^{N}\mathbf{V}_t(\mathbf{I}-\mathbf{A}_{tt})^{-1}\mathbf{A}_{ts}(\mathbf{I}-\mathbf{A}_{ss})^{-1}\mathbf{A}_{sr}(\mathbf{I}-\mathbf{A}_{rr})^{-1}\overset{\mathbf{9b*}}{\sum_{j\neq r}^{N}\mathbf{A}_{rj}\sum_{k}^{N}\sum_{l}^{N}\mathbf{B}_{jk}\mathbf{Y}_{kl}} \\
+\ & \sum_{t\neq s}^{N}\mathbf{V}_t(\mathbf{I}-\mathbf{A}_{tt})^{-1}\left[\overset{\mathbf{9c*}}{\sum_{j\neq t,s}^{N}\mathbf{A}_{tj}\mathbf{B}_{js}\mathbf{E}_{sr}}+\overset{\mathbf{9d*}}{\mathbf{A}_{ts}(\mathbf{I}-\mathbf{A}_{ss})^{-1}\sum_{t\neq s}^{N}\mathbf{A}_{st}\mathbf{B}_{ts}\mathbf{E}_{sr}}\right]. \quad (2)
\end{aligned}
$$

The alternative source-based approach decomposes the gross exports from country *s* to *r* in a similar framework by DVA and FVA (and by where they are ultimately absorbed). Table 2 provides the interpretation of each term in Equation (2). Note that Components

Table 2. Decomposition of Gross Exports by the Source-Based Approach

Gross exports from country s to r		traditional trade	(1a*) in final goods exports $\mathbf{Y}_{sr}$ directly absorbed by bilateral importers (2a*) in intermediate exports $\mathbf{A}_{sr}$ absorbed by direct importers as local final goods $\mathbf{Y}_{rr}$
	DVA	in intermediate exports $\mathbf{A}_{sr}$ *absorbed by bilateral importer r*	(1b*) as s's final goods $\mathbf{Y}_{sr}$ after additional processing stages (2b*) as local final goods $\mathbf{Y}_{rr}$ but only after further processing stages (3c*) as final goods from third countries $\mathbf{Y}_{kr}$
		in intermediate goods exports $\mathbf{A}_{sr}$ *absorbed by third countries*	(1c*) as s's final goods $\mathbf{Y}_{sk}$ after additional processing stages (2c*) as local final goods $\mathbf{Y}_{kk}$ (3a*) as final goods from direct bilateral importer $\mathbf{Y}_{rj}$ (3b*) as final goods from direct bilateral importer $\mathbf{Y}_{rl}$ but only after further processing stages (3d*) as final goods from other third countries $\mathbf{Y}_{kl}$
		in intermediate goods exports $\mathbf{A}_{sr}$ *absorbed at home*	(4a*) as final goods of the bilateral importer $\mathbf{Y}_{rs}$ (4b*) as final goods of the bilateral importer $\mathbf{Y}_{rs}$ but only after additional processing stages (4c*) as final goods of a third country $\mathbf{Y}_{ks}$ (5*) as domestic final goods $\mathbf{Y}_{ss}$
	FVA, $\mathbf{V}_{t \neq s}$		(7*) in exports of final goods $\mathbf{Y}_{sr}$ (8*) in exports of intermediate goods $\mathbf{A}_{sr}$ directly absorbed by the importing country $\mathbf{Y}_{rr}$
		in intermediate exports $\mathbf{A}_{sr}$ *re-exported by r*	(9a*) via final goods exports $\mathbf{Y}_{rj}$ (9b*) via intermediate exports $\mathbf{A}_{rj}$
	purely double-counted components		(6*) of domestic content (9c*–9d*) of foreign content

1a* and 2a* are the exporter's DVA that is directly absorbed by the importer *r*. They can be regarded as traditional trade, as the value-added component crosses borders only once. This is in contrast with the other value-added components in Equation (2) that cross national borders more than once and are plausibly associated with GVC activities.

Using the same example introduced above, now by the source-based approach, the gross exports of Singapore to China consist of only Singapore's DVA (Component 2c* or 3d*), while the gross exports of China to Singapore consist of Chinese DVA (Component 2c* or 3d*) and FVA contributed by Singapore (Component 9b*). The gross exports of Singapore to Malaysia, in turn, consist of double-counted Singaporean content created in the first stage (Component 6*), Singaporean DVA created in the second stage (Component 2c* or 3a*), and FVA contributed by China (Component 9a* or 9b*). Finally, the gross exports of Malaysia to the US include Malaysian DVA (Component 1a* or 2a*) and FVA by Singapore created in the second stage (Component 7* or 8*), and double-counted foreign contents by Singapore created in the first stage and by China (Component 9c*).

Given that the source-based approach targets the first time a DVA leaves its country of origin or the first time a FVA is re-exported, it uses the local Leontief matrix $(\mathbf{I} - \mathbf{A}_{ss})^{-1}$, pre-multiplied by the value-added share vector $\mathbf{V}_s$. At the same time, it allows for all possible forward linkages by which such VA components can be routed (including repeatedly through the same country of origin or the same re-exporter), as captured by the global Leontief matrix $\mathbf{B}$ before the final demand vector $\mathbf{Y}$.

3. Key Upstream and Downstream Trade Partners of Singapore

3.1. *Key upstream trade partners*

We start by identifying the key upstream trade partners of Singapore. To this end, define $E_{sr} = \mathbf{u}_G \mathbf{E}_{sr}$ as the bilateral gross exports of country *s* to *r* and FC_{sr}^r as the content of country *r* re-exported by country *s* to country *r* (which is foreign content *FC* from the exporter's perspective). We define

$$U_{sr} \equiv \frac{E_{sr} - FC_{sr}^r - 1a_{sr}^* - 2a_{sr}^*}{\sum_c E_{cr} - FC_{cr}^r - 1a_{cr}^* - 2a_{cr}^*} \tag{3}$$

as a measure of the relative importance of country *s* in country *r*'s backward linkages. Note that gross exports of country *s* to *r* equal the sum of foreign contents and domestic contents (from *s*'s perspective). By netting out *r*'s contents (FC_{sr}^r) and traditional trade ($1a_{sr}^* + 2a_{sr}^*$) from country *s*'s gross exports to *r*, the numerator in Equation (3) corresponds to the sum of: (i) third-country contents that exporter *s* passes on to *r*, and (ii) exporter *s*'s domestic contents that are (not directly absorbed but) further processed and re-exported by *r*.

A country *s* is regarded as being a more important upstream trade partner of country *r* than country *s'* if country *s* passes on more foreign contents from third countries to country *r*, or if country *s* contributes more contents of its own to country *r*'s gross exports.

The results for Singapore (as an importer) are reported in Tables 3–5 for 1995, 2011 and 2015, respectively (1995 and 2011 based on the TiVA 2016 edition; and 2015 based on the TiVA 2018 edition). These are the first and the last years of the TiVA tables, 2016 edition,

and the last year of the TiVA tables, 2018 edition. In 1995, Singapore's imports totaled US\$72 billion. Japan, the US, and Malaysia were the top sources of imports, followed by the other economies in the region and Europe. Columns 2 and 3 report, respectively, the Singaporean content embedded in and the traditional trade associated with each source of

Table 3. Key Upstream Trade Partners of Singapore (1995)

		$E_{s,sgp}$	$FC_{s,sgp}^{sgp}$	$TT_{s,sgp}$	$\frac{E_{s,sgp}-FC_{s,sgp}^{sgp}-TT_{s,sgp}}{E_{s,sgp}}$	$\frac{E_{s,sgp}}{\sum_{c}E_{c,sgp}}$	$U_{s,sgp}$
1	JPN	13,660,229	15,682	5,988,790	0.56044	0.18966	0.18141
2	USA	13,084,505	31,772	5,817,608	0.55295	0.18167	0.17145
3	MYS	6,755,001	131,171	2,194,759	0.65567	0.09379	0.10495
4	KOR	3,525,312	12,916	1,296,625	0.62853	0.04895	0.05251
5	THA	3,006,252	41,444	1,066,016	0.63161	0.04174	0.04499
6	SAU	2,677,991	222	904,145	0.66230	0.03718	0.04203
7	ROW	2,696,052	1,957	979,405	0.63600	0.03743	0.04063
8	TWN	2,374,675	15,295	733,698	0.68459	0.03297	0.03852
9	GBR	2,647,294	3,915	1,129,433	0.57188	0.03676	0.03587
10	IDN	3,117,687	18,630	1,653,836	0.46356	0.04329	0.03425
11	DEU	2,265,421	2,053	1,034,194	0.54258	0.03145	0.02913
12	AUS	1,946,970	6,641	947,439	0.50997	0.02703	0.02353
13	FRA	1,669,819	2,263	693,122	0.58356	0.02318	0.02309
14	CHN	1,478,082	7,505	523,268	0.64090	0.02052	0.02245
15	HKG	1,610,688	9,739	695,138	0.56238	0.02236	0.02146
16	NLD	899,057	1,136	330,305	0.63135	0.01248	0.01345
17	PHL	720,658	8,312	196,366	0.71598	0.01001	0.01223
18	ITA	969,217	530	494,842	0.48889	0.01346	0.01123
19	CHE	731,326	328	296,963	0.59349	0.01015	0.01028
20	IND	760,200	1,406	364,372	0.51884	0.01055	0.00935
21	NOR	526,275	781	204,229	0.61045	0.00731	0.00761
22	SWE	444,113	722	177,466	0.59878	0.00617	0.00630
23	CAN	416,364	306	176,565	0.57520	0.00578	0.00568
24	DNK	274,098	1,062	94,766	0.65039	0.00381	0.00422
25	VNM	250,320	3,821	75,003	0.68511	0.00348	0.00406
26	BEL	269,698	176	99,229	0.63142	0.00374	0.00404
27	TUR	282,781	80	113,223	0.59932	0.00393	0.00402
28	BRA	279,386	172	116,245	0.58331	0.00388	0.00386
29	ESP	299,046	219	145,412	0.51302	0.00415	0.00364
30	ISR	291,376	651	142,402	0.50904	0.00405	0.00351
31	FIN	213,892	292	68,164	0.67995	0.00297	0.00345
32	LUX	176,030	44	46,253	0.73700	0.00244	0.00307
33	RUS	202,051	105	92,385	0.54225	0.00281	0.00260
34	IRL	116,306	2,509	22,054	0.78881	0.00161	0.00217
35	BRN	134,713	1,214	45,833	0.65076	0.00187	0.00208
36	AUT	171,924	135	84,507	0.50768	0.00239	0.00207

Table 3. (*Continued*)

		$E_{s,sgp}$	$FC^{sgp}_{s,sgp}$	$TT_{s,sgp}$	$\frac{E_{s,sgp}-FC^{sgp}_{s,sgp}-TT_{s,sgp}}{E_{s,sgp}}$	$\frac{E_{s,sgp}}{\sum_{c}E_{c,sgp}}$	$U_{s,sgp}$
37	CHL	161,087	78	78,215	0.51397	0.00224	0.00196
38	ZAF	145,329	116	63,407	0.56291	0.00202	0.00194
39	NZL	133,069	494	52,886	0.59886	0.00185	0.00189
40	MEX	128,630	127	55,696	0.56602	0.00179	0.00173
41	MLT	64,947	3,131	7,065	0.84301	0.00090	0.00130
42	PRT	83,743	31	32,895	0.60682	0.00116	0.00120
43	ROU	72,511	27	27,437	0.62124	0.00101	0.00107
44	CZE	45,930	17	19,718	0.57033	0.00064	0.00062
45	POL	44,740	19	20,000	0.55255	0.00062	0.00059
46	HUN	35,410	14	10,677	0.69808	0.00049	0.00059
47	ARG	38,698	11	19,393	0.49857	0.00054	0.00046
48	GRC	22,830	8	10,176	0.55394	0.00032	0.00030
49	SVN	15,465	3	5,786	0.62566	0.00021	0.00023
50	CYP	9,223	6	3,513	0.61845	0.00013	0.00014
51	COL	11,888	2	6,679	0.43801	0.00017	0.00012
52	KHM	10,905	45	6,408	0.40827	0.00015	0.00011
53	CRI	8,036	4	3,795	0.52735	0.00011	0.00010
54	BGR	6,143	2	1,976	0.67798	0.00009	0.00010
55	LTU	6,435	2	3,106	0.51706	0.00009	0.00008
56	SVK	4,049	1	1,173	0.71013	0.00006	0.00007
57	LVA	4,226	1	1,587	0.62427	0.00006	0.00006
58	HRV	2,908	0	1,203	0.58623	0.00004	0.00004
59	EST	2,290	1	775	0.66101	0.00003	0.00004
60	ISL	2,177	1	864	0.60241	0.00003	0.00003
61	PER	6,721	2	5,535	0.17623	0.00009	0.00003
62	MAR	9,926	1	8,743	0.11903	0.00014	0.00003
63	TUN	1,267	1	469	0.62932	0.00002	0.00002
	Total	72,023,392	329,347	29,493,235	0.58593	1	1

Note: The results are based on the TiVA 2016 edition. The bilateral gross exports ($E_{s,sgp}$), the Singapore contents in the bilateral gross exports ($FC^{sgp}_{s,sgp}$), and the traditional trade in the bilateral gross exports ($TT_{s,sgp}$) are in thousands. $TT_{s,sgp} = 1a^{*}_{s,sgp} + 2a^{*}_{s,sgp}$.

imports ($TT_{s,sgp} \equiv 1a^{*}_{s,sgp} + 2a^{*}_{s,sgp}$). The proportion of Singaporean content $FC^{sgp}_{s,sgp}$ relative to trade flows $E_{s,sgp}$ was negligible, at less than 1% typically. Meanwhile, about 40% of bilateral imports were associated with traditional trade. This implies that, on average, approximately 59% of Singaporean imports were foreign contents associated with GVC trade. The ranking of bilateral upstreamness across trade partners ($U_{s,sgp}$ by Equation (3)) followed closely the ranking of bilateral exports to Singapore. Thus, Japan and the US were the key upstream trade partners of Singapore, from which Singapore imported more than 35% of foreign contents associated with GVC trade. They were followed by key regional upstream trade partners such as Malaysia, Korea, Thailand and Saudi Arabia.

Table 4. Key Upstream Trade Partners of Singapore (2011)

		$E_{s,sgp}$	$FC_{s,sgp}^{sgp}$	$TT_{s,sgp}$	$\frac{E_{s,sgp}-FC_{s,sgp}^{sgp}-TT_{s,sgp}}{E_{s,sgp}}$	$\frac{E_{s,sgp}}{\sum_c E_{c,sgp}}$	$U_{s,sgp}$
1	USA	26,527,441	28,374	11,596,079	0.56180	0.13063	0.11426
2	CHN	16,708,279	58,633	6,103,889	0.63117	0.08228	0.08086
3	ROW	16,133,922	15,354	5,766,132	0.64166	0.07945	0.07937
4	JPN	12,591,010	15,590	3,894,230	0.68948	0.06200	0.06656
5	IND	13,567,018	52,065	4,923,164	0.63329	0.06681	0.06587
6	MYS	10,394,505	203,997	3,408,274	0.65248	0.05119	0.05200
7	SAU	8,970,694	1,715	2,962,128	0.66961	0.04417	0.04605
8	TWN	7,186,749	38,302	1,293,520	0.81468	0.03539	0.04489
9	GBR	9,935,548	24,112	4,110,309	0.58388	0.04893	0.04448
10	KOR	7,730,425	32,892	1,953,939	0.74299	0.03807	0.04404
11	IDN	7,581,100	38,149	2,760,921	0.63078	0.03733	0.03666
12	NLD	6,017,509	11,685	2,186,021	0.63478	0.02963	0.02929
13	DEU	5,738,821	8,730	2,016,238	0.64715	0.02826	0.02847
14	THA	5,224,229	39,927	1,494,061	0.70637	0.02573	0.02829
15	FRA	4,712,709	6,938	1,599,974	0.65903	0.02321	0.02381
16	AUS	5,470,737	23,761	2,389,785	0.55883	0.02694	0.02344
17	HKG	4,493,195	40,347	1,903,673	0.56734	0.02213	0.01954
18	CHE	3,668,260	4,254	1,749,444	0.52193	0.01806	0.01468
19	BRA	2,304,018	1,232	787,583	0.65763	0.01135	0.01162
20	NOR	1,970,136	7,315	505,912	0.73950	0.00970	0.01117
21	PHL	1,909,888	13,310	494,183	0.73428	0.00940	0.01075
22	IRL	1,809,273	3,213	611,884	0.66003	0.00891	0.00916
23	ISR	2,161,908	5,265	976,651	0.54581	0.01065	0.00905
24	CAN	1,627,596	1,208	497,042	0.69387	0.00801	0.00866
25	ITA	1,684,310	1,268	574,612	0.65809	0.00829	0.00850
26	LUX	1,301,442	24,007	250,643	0.78897	0.00641	0.00787
27	DNK	1,264,838	10,501	231,327	0.80881	0.00623	0.00784
28	RUS	1,184,866	596	267,251	0.77394	0.00583	0.00703
29	BEL	1,315,669	1,913	412,505	0.68501	0.00648	0.00691
30	GRC	1,006,520	3,005	202,983	0.79535	0.00496	0.00614
31	SWE	1,163,204	1,235	361,633	0.68804	0.00573	0.00614
32	ESP	1,016,498	577	268,695	0.73510	0.00501	0.00573
33	VNM	1,016,985	7,892	368,844	0.62956	0.00501	0.00491
34	PRT	951,285	931	315,916	0.66693	0.00468	0.00486
35	NZL	904,558	3,462	315,995	0.64684	0.00445	0.00449
36	ARG	932,108	821	421,793	0.54660	0.00459	0.00391
37	TUR	772,528	620	324,828	0.57872	0.00380	0.00343
38	HUN	359,175	1,408	65,237	0.81445	0.00177	0.00224
39	FIN	405,661	599	132,707	0.67139	0.00200	0.00209
40	MEX	487,611	873	220,093	0.54684	0.00240	0.00204
41	ZAF	612,756	818	359,653	0.41172	0.00302	0.00193
42	CHL	358,559	160	157,424	0.56051	0.00177	0.00154
43	AUT	277,825	183	90,447	0.67379	0.00137	0.00144

Table 4. (*Continued*)

		$E_{s,sgp}$	$FC^{sgp}_{s,sgp}$	$TT_{s,sgp}$	$\dfrac{E_{s,sgp}-FC^{sgp}_{s,sgp}-TT_{s,sgp}}{E_{s,sgp}}$	$\dfrac{E_{s,sgp}}{\sum_c E_{c,sgp}}$	$U_{s,sgp}$
44	CZE	235,652	275	59,250	0.74740	0.00116	0.00135
45	COL	228,562	48	60,189	0.73645	0.00113	0.00129
46	POL	220,024	127	59,104	0.73080	0.00108	0.00123
47	MAR	219,365	947	131,832	0.39471	0.00108	0.00066
48	KHM	147,118	919	66,620	0.54092	0.00072	0.00061
49	CRI	122,336	92	47,668	0.60960	0.00060	0.00057
50	BGR	67,414	27	4,594	0.93145	0.00033	0.00048
51	ROU	81,256	38	32,130	0.60411	0.00040	0.00038
52	EST	52,497	44	10,311	0.80275	0.00026	0.00032
53	HRV	46,955	13	14,654	0.68763	0.00023	0.00025
54	LVA	35,355	15	8,822	0.75004	0.00017	0.00020
55	BRN	43,646	683	16,453	0.60738	0.00021	0.00020
56	SVN	27,356	20	8,633	0.68369	0.00013	0.00014
57	PER	59,635	16	49,660	0.16701	0.00029	0.00008
58	SVK	11,830	12	3,012	0.74434	0.00006	0.00007
59	LTU	9,341	3	1,380	0.85185	0.00005	0.00006
60	CYP	8,046	4	3,672	0.54315	0.00004	0.00003
61	MLT	4,952	43	1,152	0.75881	0.00002	0.00003
62	ISL	1,942	3	648	0.66490	0.00001	0.00001
63	TUN	1,685	1	429	0.74494	0.00001	0.00001
	Total	203,076,335	740,565	71,907,835	0.64226	1	1

Note: The results are based on the TiVA 2016 edition. The bilateral gross exports ($E_{s,sgp}$), the Singapore contents in the bilateral gross exports ($FC^{sgp}_{s,sgp}$), and the traditional trade in the bilateral gross exports ($TT_{s,sgp}$) are in thousands. $TT_{s,sgp} = 1a^*_{s,sgp} + 2a^*_{s,sgp}$.

In 2011, Singapore's imports almost tripled to US$203 billion. The key upstream trade partners changed in composition, with the US at the top, followed by China and the rest of the world. Japan and Malaysia dropped to the 4th and 6th places, respectively. Korea and Thailand also lost significance. In contrast, India rose significantly in its ranking (from 20th to 5th). Meanwhile, Singapore also became more diversified in its sourcing. Its network, in 2011, spread more evenly across regional as well as cross-continental suppliers, with the index $U_{s,sgp}$ being less concentrated among the top trade partners.

In 2015, the US remained the most important upstream partner of Singapore. The rest of the world intermediated an equally significant portion of foreign contents to Singapore, which suggested a very diverse sourcing pattern of Singapore. China appeared to be less significant relative to Japan during 2011–2015 based on the TiVA tables, 2018 edition. Saudi Arabia's importance as Singapore's upstream partner meanwhile decreased by nearly half. Otherwise, the set of top 10 upstream partners of Singapore remained similar during the short period of 2011–2015.

Table 5. Key Upstream Trade Partners of Singapore (2015)

		$E_{s,sgp}$	$FC_{s,sgp}^{sgp}$	$TT_{s,sgp}$	$\dfrac{E_{s,sgp}-FC_{s,sgp}^{sgp}-TT_{s,sgp}}{E_{s,sgp}}$	$\dfrac{E_{s,sgp}}{\sum_c E_{c,sgp}}$	$U_{s,sgp}$
1	USA	36,789,263	26,992	18,283,301	0.50229	0.16429	0.13282
2	ROW	24,625,327	44,136	6,302,950	0.74225	0.10997	0.13138
3	JPN	23,754,708	56,099	8,904,514	0.62279	0.10608	0.10634
4	CHN	11,937,314	21,404	4,994,212	0.57984	0.05331	0.04975
5	MYS	11,565,898	166,276	4,549,400	0.59228	0.05165	0.04924
6	IND	11,462,762	34,386	4,581,937	0.59728	0.05119	0.04921
7	IDN	8,390,526	58,169	2,970,958	0.63898	0.03747	0.03854
8	GBR	9,383,981	13,413	4,055,604	0.56639	0.04191	0.03820
9	KOR	7,136,769	28,504	2,169,159	0.69206	0.03187	0.03550
10	TWN	6,624,374	30,930	1,787,913	0.72543	0.02958	0.03454
11	DEU	7,372,194	14,698	3,022,617	0.58800	0.03292	0.03116
12	SAU	4,431,372	2,623	825,088	0.81322	0.01979	0.02590
13	THA	5,853,072	37,655	2,220,579	0.61418	0.02614	0.02584
14	NLD	4,908,435	27,541	1,434,267	0.70218	0.02192	0.02477
15	FRA	5,231,815	8,031	2,073,974	0.60205	0.02336	0.02264
16	AUS	5,454,223	22,188	2,332,360	0.56831	0.02436	0.02228
17	HKG	4,667,050	56,688	1,666,220	0.63084	0.02084	0.02116
18	CHE	4,051,101	11,712	1,620,997	0.59697	0.01809	0.01738
19	RUS	2,835,233	1,435	806,984	0.71487	0.01266	0.01457
20	PHL	3,112,715	18,965	1,186,857	0.61261	0.01390	0.01371
21	VNM	2,478,479	22,478	668,850	0.72107	0.01107	0.01285
22	DNK	1,736,918	25,153	304,636	0.81013	0.00776	0.01011
23	IRL	1,917,720	42,197	496,164	0.71927	0.00856	0.00991
24	NOR	1,867,749	4,495	589,710	0.68186	0.00834	0.00915
25	BEL	1,407,135	3,889	405,640	0.70896	0.00628	0.00717
26	ITA	1,660,925	1,786	744,558	0.55065	0.00742	0.00657
27	BRA	1,302,364	809	464,679	0.64258	0.00582	0.00602
28	LUX	880,782	30,036	94,495	0.85861	0.00393	0.00544
29	CAN	1,123,007	830	482,859	0.56929	0.00502	0.00460
30	ISR	921,885	2,923	396,556	0.56667	0.00412	0.00375
31	SWE	911,104	881	391,015	0.56987	0.00407	0.00373
32	GRC	673,587	612	161,149	0.75985	0.00301	0.00368
33	ESP	869,557	607	371,919	0.57159	0.00388	0.00357
34	MEX	715,995	772	268,416	0.62404	0.00320	0.00321
35	TUR	682,776	471	282,518	0.58553	0.00305	0.00287
36	NZL	792,441	3,586	417,712	0.46835	0.00354	0.00267
37	ZAF	671,375	1,249	313,851	0.53066	0.00300	0.00256
38	COL	351,662	223	94,774	0.72986	0.00157	0.00184
39	AUT	374,835	394	166,627	0.55442	0.00167	0.00149
40	MAR	248,988	624	81,519	0.67009	0.00111	0.00120
41	POL	273,923	381	107,528	0.60606	0.00122	0.00119
42	HUN	222,290	425	66,101	0.70072	0.00099	0.00112
43	BGR	149,280	123	24,530	0.83485	0.00067	0.00090

Table 5. (*Continued*)

		$E_{s,sgp}$	$FC^{sgp}_{s,sgp}$	$TT_{s,sgp}$	$\frac{E_{s,sgp}-FC^{sgp}_{s,sgp}-TT_{s,sgp}}{E_{s,sgp}}$	$\frac{E_{s,sgp}}{\sum_c E_{c,sgp}}$	$U_{s,sgp}$
44	FIN	208,062	389	83,100	0.59873	0.00093	0.00090
45	CYP	158,052	531	40,215	0.74220	0.00071	0.00084
46	ROU	198,260	118	88,277	0.55414	0.00089	0.00079
47	PRT	172,543	112	68,634	0.60157	0.00077	0.00075
48	KHM	189,838	2,948	88,175	0.52000	0.00085	0.00071
49	CZE	154,958	227	59,716	0.61317	0.00069	0.00068
50	BRN	115,185	1,288	28,455	0.74178	0.00051	0.00061
51	CRI	166,632	79	81,798	0.50863	0.00074	0.00061
52	EST	111,561	157	27,491	0.75217	0.00050	0.00060
53	ARG	124,180	42	51,505	0.58490	0.00055	0.00052
54	MLT	96,740	910	27,463	0.70671	0.00043	0.00049
55	CHL	86,361	60	33,243	0.61437	0.00039	0.00038
56	LTU	69,161	44	17,056	0.75276	0.00031	0.00037
57	HRV	57,061	49	19,255	0.66169	0.00025	0.00027
58	SVN	48,333	60	18,581	0.61431	0.00022	0.00021
59	KAZ	29,253	8	5,767	0.80261	0.00013	0.00017
60	SVK	34,273	42	11,384	0.66661	0.00015	0.00016
61	LVA	29,298	30	9,855	0.66261	0.00013	0.00014
62	PER	28,261	18	13,098	0.53587	0.00013	0.00011
63	TUN	13,299	14	5,223	0.60616	0.00006	0.00006
64	ISL	12,523	13	5,952	0.52370	0.00006	0.00005
	Total	223,926,740	833,924	83,969,943	0.62129	1	1

Note: The results are based on the TiVA 2018 edition. The bilateral gross exports ($E_{s,sgp}$), the Singapore contents in the bilateral gross exports ($FC^{sgp}_{s,sgp}$), and the traditional trade in the bilateral gross exports ($TT_{s,sgp}$) are in thousands. $TT_{s,sgp} = 1a^*_{s,sgp} + 2a^*_{s,sgp}$.

3.2. *Key downstream trade partners*

In this section, we identify the key downstream trade partners of Singapore. For this purpose, we use the sink-based approach in Equation (1) and calculate the Singaporean DVA absorbed abroad embedded in its gross exports $E_{sgp,r}$ with respect to each trade partner r. This corresponds to the sum of Components 1–3d. The sum is further disaggregated into those DVA that are absorbed by the bilateral importer r (Components 1, 2a–2b, and 3c), and those that pass through r with further processing stages before reaching third countries as final destination markets (2c, 3a–3b, and 3d). A trade partner r is considered a key downstream partner if a significant portion of Singaporean DVA is intermediated by the country before reaching the final destination.

The sink-based approach is adopted here because the DVA components in this approach pick up the Singaporean content that leaves Singapore for the last time, and hence is the closest possible to its final destination market for absorption. In a way, this measure

(following Borin and Mancini, 2017) focuses on the production linkages toward the end of the global value chain (and the downstream trade partner of Singapore in this spectrum).[4]

Tables 6–8 present the results for 1995, 2011 and 2015, respectively, by the region where Singapore's DVA was finally absorbed. The set of countries included in each region are listed in Table A.1. In 1995, a large portion of Singapore's DVA was absorbed by the countries in Asia Pacific, followed by NAFTA and Europe. On average, more than 80% of Singapore's DVA was absorbed by the bilateral importer. For the remaining DVA absorbed abroad, the US and Malaysia were the most important downstream partners of Singapore. Together, they intermediated 4.7% of Singapore's DVA absorbed abroad. Ireland also played a key intermediary role for Singapore's DVA absorbed by European markets.

In 2011, the fraction of Singapore's DVA that was absorbed by the bilateral importer decreased substantially (by about 8% points for the world market as a whole). This drop was especially large for non-Asian destinations. This in a way signifies a longer (or more fragmented) value chain for Singapore's exports. In 2011, China replaced the US as the most important downstream trade partner of Singapore. The intermediary role of China was indeed more important for distant markets (Europe, NAFTA and Latin America) than for nearby Asian destinations.

In 2015, the fraction of Singapore's DVA that was absorbed by the bilateral importer decreased even further for non-Asian destination markets. Note that the European markets became the second most important destinations (after Asia) for Singapore's DVA, and the fraction of such DVA that was absorbed by the bilateral importers decreased during 1995–2015. In turn, Ireland played a dominant intermediary role for Singapore's DVA destined for the European markets. At the same time, while China played the key downstream intermediary role for several destination markets, these other markets were either smaller in size (such as Latin American markets) or had smaller fractions of Singapore's DVA being intermediated (e.g., Asian markets). As a result, Ireland stood out as the most important downstream trade partner of Singapore in 2015.

We conduct similar analysis for major Asian exporters (Japan, Taiwan, Korea, China and Hong Kong) as comparison. The most important downstream trade partners of Japan were the US and Taiwan in 1995, but they were replaced by China and Korea in 2011–2015. A large fraction of the Japanese DVA that used to be directly absorbed by Europe, NAFTA and Latin America in 1995 now passed through China before reaching these destinations. The prominent intermediary role of China for the Japanese DVA appeared to be weaker in 2015 based on the TiVA 2018 edition.

Taiwan's export structures underwent similar transformations. Between 1995 and 2011, the fraction of the Taiwanese DVA absorbed by the bilateral importer dropped significantly (in fact, reaching the lowest level among this set of Asian economies in 2011). China already played a significant role in 1995 as Taiwan's key downstream trade partner, and this importance was even more pronounced in 2011. More than 25% of the Taiwanese

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[4] It is possible to construct alternative measures that take into account not only Singapore's VA but also foreign contents that are received by a trade partner from Singapore. In this case, a trade partner may not intermediate significant amounts of Singapore's DVA but still be an important downstream partner if Singapore passes on a substantial amount of third-country contents to the country.

Table 6. Key Downstream Trade Partners of Singapore and Other Asian Economies (1995)

SINGAPORE	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of total gross export	100.00	50.85	17.39	23.76	1.68	6.07
% of total DVA absorbed by the market	100.00	46.52	19.32	24.28	2.20	7.29
% of DVA absorbed by the bilateral importer	83.37	89.49	70.37	83.63	80.15	78.78
% of DVA 1st intermediate importer	USA (2.83)	USA (1.81)	USA (4.67)	MYS (2.39)	USA (7.06)	USA (5.40)
% of DVA 2nd intermediate importer	MYS (1.89)	MYS (1.54)	IRL (2.78)	USA (2.20)	MYS (1.51)	MYS (1.71)
% of DVA 3rd intermediate importer	TWN (1.12)	CHN (0.84)	MYS (2.24)	TWN (1.61)	ROW (1.07)	TWN (1.25)
% of DVA 4th intermediate importer	CHN (1.03)	THA (0.82)	GBR (2.09)	JPN (1.26)	KOR (1.00)	CHN (1.19)
% of DVA 5th intermediate importer	THA (1.02)	TWN (0.80)	DEU (1.79)	CHN (1.22)	TWN (0.94)	GBR (1.06)
JAPAN						
% of total gross export	100.00	39.99	18.88	31.91	1.54	7.26
% of total DVA absorbed by the market	100.00	33.36	21.73	33.66	2.05	8.71
% of DVA absorbed by the bilateral importer	82.05	88.71	71.05	84.07	72.14	77.92
% of DVA 1st intermediate importer	USA (3.17)	USA (1.89)	USA (4.87)	TWN (2.53)	USA (9.78)	USA (6.02)
% of DVA 2nd intermediate importer	TWN (2.21)	TWN (1.76)	DEU (2.54)	USA (2.24)	KOR (2.69)	TWN (2.45)
% of DVA 3rd intermediate importer	CHN (1.71)	SGP (1.36)	TWN (2.34)	CHN (1.92)	TWN (2.31)	KOR (2.20)
% of DVA 4th intermediate importer	KOR (1.48)	CHN (1.21)	CHN (2.18)	KOR (1.51)	ROW (1.97)	CHN (1.74)
% of DVA 5th intermediate importer	SGP (1.35)	KOR (1.06)	GBR (1.87)	SGP (1.32)	CHN (1.70)	SGP (1.09)
TAIWAN						
% of total gross export	100.00	44.43	15.14	30.20	1.41	8.60
% of total DVA absorbed by the market	100.00	39.65	17.43	31.14	1.80	9.63
% of DVA absorbed by the bilateral importer	82.22	86.84	68.31	84.42	73.48	82.58
% of DVA 1st intermediate importer	CHN (4.60)	CHN (4.28)	CHN (6.00)	CHN (4.62)	USA (8.98)	USA (4.39)
% of DVA 2nd intermediate importer	USA (2.86)	USA (2.07)	USA (5.01)	USA (1.88)	CHN (4.10)	CHN (3.50)

Table 6. (*Continued*)

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of DVA 3rd intermediate importer	SGP (0.96)	SGP (0.99)	DEU (2.44)	JPN (1.03)	ROW (2.15)	HKG (1.02)
% of DVA 4th intermediate importer	JPN (0.88)	MYS (0.83)	ROW (1.84)	SGP (0.90)	KOR (1.11)	JPN (0.82)
% of DVA 5th intermediate importer	MYS (0.86)	HKG (0.71)	GBR (1.42)	CAN (0.88)	HKG (1.09)	KOR (0.73)

KOREA

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of total gross export	100.00	44.11	16.97	25.40	2.59	10.58
% of total DVA absorbed by the market	100.00	39.00	19.26	26.98	2.93	11.40
% of DVA absorbed by the bilateral importer	83.00	87.93	71.53	82.68	84.25	85.65
% of DVA 1st intermediate importer	CHN (3.00)	CHN (2.79)	USA (3.98)	CHN (3.51)	USA (4.75)	USA (3.16)
% of DVA 2nd intermediate importer	USA (2.44)	USA (1.69)	CHN (3.57)	USA (1.90)	ROW (1.70)	CHN (1.96)
% of DVA 3rd intermediate importer	TWN (1.36)	SGP (1.15)	DEU (2.05)	TWN (1.77)	CHN (1.63)	TWN (1.10)
% of DVA 4th intermediate importer	SGP (1.12)	TWN (1.15)	ROW (1.89)	JPN (1.43)	TWN (0.88)	JPN (0.84)
% of DVA 5th intermediate importer	JPN (1.05)	JPN (0.77)	TWN (1.47)	CAN (1.37)	SGP (0.82)	HKG (0.67)

CHINA

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of total gross export	100.00	45.46	19.58	26.23	1.15	7.45
% of total DVA absorbed by the market	100.00	44.84	19.81	25.43	1.34	8.39
% of DVA absorbed by the bilateral importer	88.92	93.07	80.91	89.83	76.00	85.19

Table 6. (*Continued*)

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of DVA 1st intermediate importer	HKG (1.58)	HKG (1.38)	USA (2.21)	USA (1.33)	USA (6.56)	HKG (2.98)
% of DVA 2nd intermediate importer	USA (1.54)	USA (1.00)	DEU (1.86)	HKG (1.33)	HKG (3.40)	USA (2.72)
% of DVA 3rd intermediate importer	KOR (0.99)	KOR (0.86)	HKG (1.68)	JPN (1.19)	ROW (2.33)	KOR (1.49)
% of DVA 4th intermediate importer	JPN (0.90)	JPN (0.67)	ROW (1.31)	KOR (1.04)	KOR (2.24)	JPN (1.00)
% of DVA 5th intermediate importer	TWN (0.65)	TWN (0.54)	ITA (1.23)	TWN (0.83)	JPN (1.43)	TWN (0.82)
HONG KONG						
% of total gross export	100.00	54.73	15.47	15.93	1.89	10.18
% of total DVA absorbed by the market	100.00	48.98	17.61	19.30	2.06	10.01
% of DVA absorbed by the bilateral importer	84.28	89.85	72.93	78.26	81.91	86.41
% of DVA 1st intermediate importer	CHN (4.55)	CHN (3.30)	CHN (6.12)	CHN (7.35)	CHN (3.90)	CHN (3.54)
% of DVA 2nd intermediate importer	SGP (1.43)	SGP (1.32)	ROW (2.08)	TWN (2.04)	USA (2.32)	TWN (1.27)
% of DVA 3rd intermediate importer	TWN (1.23)	TWN (0.95)	GBR (1.66)	SGP (1.92)	ROW (2.12)	USA (1.19)
% of DVA 4th intermediate importer	MYS (0.93)	MYS (0.84)	SGP (1.58)	ROW (1.48)	SGP (1.56)	SGP (1.04)
% of DVA 5th intermediate importer	ROW (0.87)	USA (0.53)	DEU (1.53)	MYS (1.23)	TWN (1.18)	MYS (0.70)

Note: The results are based on the TiVA 2016 edition. In each case, total DVA of a country absorbed by a market corresponds to the sum of Components 1–3d. DVA absorbed by the bilateral importer corresponds to the sum of Components 1, 2a–2b, and 3c. The ranking of downstream partners is based on the amount of DVA that is intermediated by a trade partner before reaching third-country final destination markets (cf. Components 2c, 3a–3b, and 3d).

Table 7. Key Downstream Trade Partners of Singapore and Other Asian Economies (2011)

SINGAPORE	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of total gross export	100.00	62.19	15.25	11.06	1.74	9.20
% of total DVA absorbed by the market	100.00	51.41	17.57	16.37	2.49	11.28
% of DVA absorbed by the bilateral importer	74.96	82.90	60.99	67.33	65.53	73.10
% of DVA 1st intermediate importer	CHN (4.95)	MYS (3.78)	CHN (6.49)	CHN (9.57)	CHN (9.32)	CHN (5.53)
% of DVA 2nd intermediate importer	MYS (3.71)	CHN (2.71)	DEU (3.02)	MYS (4.77)	MYS (4.28)	MYS (3.28)
% of DVA 3rd intermediate importer	KOR (1.59)	KOR (1.44)	MYS (2.88)	KOR (2.03)	USA (2.67)	THA (2.21)
% of DVA 4th intermediate importer	THA (1.46)	TWN (1.36)	LUX (2.70)	TWN (1.83)	KOR (2.56)	IND (1.95)
% of DVA 5th intermediate importer	TWN (1.30)	THA (1.01)	GBR (2.56)	THA (1.35)	THA (1.58)	KOR (1.73)
JAPAN						
% of total gross export	100.00	56.57	12.55	18.89	1.70	9.78
% of total DVA absorbed by the market	100.00	42.96	16.41	24.23	2.75	13.03
% of DVA absorbed by the bilateral importer	73.03	82.17	57.72	69.79	57.01	70.84
% of DVA 1st intermediate importer	CHN (8.97)	CHN (4.16)	CHN (13.83)	CHN (12.92)	CHN (17.16)	CHN (10.09)
% of DVA 2nd intermediate importer	KOR (3.26)	TWN (2.89)	KOR (3.70)	KOR (2.87)	KOR (5.41)	KOR (4.35)
% of DVA 3rd intermediate importer	TWN (2.59)	KOR (2.88)	DEU (3.06)	TWN (2.63)	USA (3.96)	USA (2.33)
% of DVA 4th intermediate importer	USA (1.64)	THA (1.61)	TWN (2.52)	MEX (2.05)	TWN (2.98)	THA (2.24)
% of DVA 5th intermediate importer	THA (1.55)	MYS (1.34)	USA (2.39)	USA (2.03)	THA (2.16)	TWN (1.66)
TAIWAN						
% of total gross export	100.00	70.19	9.04	14.38	1.72	4.30
% of total DVA absorbed by the market	100.00	52.76	13.89	22.15	2.79	7.84
% of DVA absorbed by the bilateral importer	68.23	81.62	44.69	58.99	52.38	50.31
% of DVA 1st intermediate importer	CHN (17.33)	CHN (8.69)	CHN (28.78)	CHN (26.58)	CHN (29.88)	CHN (25.86)
% of DVA 2nd intermediate importer	KOR (1.94)	KOR (1.67)	KOR (2.28)	MEX (1.98)	KOR (2.83)	KOR (3.14)

Table 7. (*Continued*)

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of DVA 3rd intermediate importer	MYS (1.55)	MYS (1.53)	DEU (2.16)	KOR (1.87)	USA (2.75)	USA (2.91)
% of DVA 4th intermediate importer	SGP (1.22)	SGP (1.30)	USA (2.14)	MYS (1.54)	MYS (1.59)	MYS (1.90)
% of DVA 5th intermediate importer	USA (1.20)	THA (0.91)	MYS (1.52)	USA (1.27)	MEX (1.27)	THA (1.90)
KOREA						
% of total gross export	100.00	56.96	13.11	14.16	3.15	12.48
% of total DVA absorbed by the market	100.00	42.66	17.17	20.23	4.08	15.63
% of DVA absorbed by the bilateral importer	74.06	83.03	59.60	64.48	73.32	78.08
% of DVA 1st intermediate importer	CHN (12.31)	CHN (7.36)	CHN (17.02)	CHN (20.25)	CHN (14.62)	CHN (9.90)
% of DVA 2nd intermediate importer	TWN (1.37)	TWN (1.66)	ROW (2.51)	MEX (2.89)	USA (1.93)	USA (1.41)
% of DVA 3rd intermediate importer	USA (1.21)	JPN (0.98)	DEU (2.23)	USA (1.63)	ROW (1.48)	DEU (1.05)
% of DVA 4th intermediate importer	JPN (1.00)	SGP (0.89)	USA (1.70)	TWN (1.58)	MEX (1.16)	RUS (091)
% of DVA 5th intermediate importer	ROW (0.96)	MYS (0.83)	RUS (1.23)	CAN (1.24)	TWN (1.00)	JPN (0.88)
CHINA						
% of total gross export	100.00	34.01	23.53	25.98	3.87	12.23
% of total DVA absorbed by the market	100.00	30.15	24.79	26.25	4.19	14.11
% of DVA absorbed by the bilateral importer	84.57	89.26	77.86	85.94	85.21	83.36

Table 7. (*Continued*)

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of DVA 1st intermediate importer	USA (1.66)	KOR (1.22)	DEU (2.17)	MEX (2.65)	USA (2.72)	USA (2.28)
% of DVA 2nd intermediate importer	KOR (1.29)	USA (1.17)	USA (1.76)	USA (1.68)	KOR (1.63)	KOR (1.94)
% of DVA 3rd intermediate importer	DEU (0.90)	JPN (0.92)	ROW (1.61)	KOR (1.14)	ROW (1.28)	IND (1.06)
% of DVA 4th intermediate importer	MEX (0.89)	SGP (0.73)	FRA (1.29)	CAN (1.11)	MEX (1.28)	JPN (0.99)
% of DVA 5th intermediate importer	JPN (0.88)	THA (0.69)	KOR (1.11)	JPN (0.99)	JPN (0.67)	RUS (0.92)
HONG KONG						
% of total gross export	100.00	63.53	13.76	13.19	0.76	7.74
% of total DVA absorbed by the market	100.00	54.29	15.42	18.08	1.45	9.51
% of DVA absorbed by the bilateral importer	78.25	87.20	61.05	72.08	44.31	70.60
% of DVA 1st intermediate importer	CHN (8.50)	CHN (4.30)	CHN (13.49)	CHN (14.32)	CHN (26.93)	CHN (11.63)
% of DVA 2nd intermediate importer	SGP (1.75)	SGP (1.70)	DEU (2.83)	SGP (1.63)	USA (3.53)	SGP (2.22)
% of DVA 3rd intermediate importer	KOR (1.08)	TWN (0.99)	SGP (1.77)	CAN (1.39)	SGP (3.40)	KOR (1.72)
% of DVA 4th intermediate importer	TWN (1.02)	KOR (0.92)	LUX (1.76)	TWN (1.19)	KOR (3.06)	IND (1.44)
% of DVA 5th intermediate importer	MYS (0.85)	MYS (0.86)	GBR (1.67)	KOR (1.10)	TWN (2.02)	MYS (1.18)

Note: The results are based on the TiVA 2016 edition. In each case, total DVA of a country absorbed by a market corresponds to the sum of Components 1–3d. DVA absorbed by the bilateral importer corresponds to the sum of Components 1, 2a–2b, and 3c. The ranking of downstream partners is based on the amount of DVA that is intermediated by a trade partner before reaching third-country final destination markets (cf. Components 2c, 3a–3b, and 3d).

Table 8. Key Downstream Trade Partners of Singapore and Other Asian Economies (2015)

SINGAPORE	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of total gross export	100.00	58.15	19.78	9.21	0.66	12.20
% of total DVA absorbed by the market	100.00	50.04	21.24	13.93	1.37	13.41
% of DVA absorbed by the bilateral importer	72.76	82.89	56.54	62.52	45.30	74.09
% of DVA 1st intermediate importer	IRL (4.05)	MYS (2.55)	IRL (12.31)	CHN (7.47)	CHN (10.66)	CHN (3.70)
% of DVA 2nd intermediate importer	CHN (3.14)	KOR (1.64)	LUX (5.21)	MYS (4.35)	IRL (5.08)	IRL (2.78)
% of DVA 3rd intermediate importer	MYS (2.53)	CHN (1.53)	CHN (3.24)	IRL (2.96)	NLD (4.25)	MYS (1.86)
% of DVA 4th intermediate importer	KOR (1.66)	TWN (1.52)	NLD (2.98)	KOR (2.40)	MYS (4.02)	KOR (1.63)
% of DVA 5th intermediate importer	LUX (1.54)	IRL (1.16)	DEU (2.62)	TWN (1.82)	KOR (3.45)	THA (1.21)
JAPAN						
% of total gross export	100.00	52.52	12.92	22.09	1.58	10.88
% of total DVA absorbed by the market	100.00	44.08	14.81	25.63	2.13	13.34
% of DVA absorbed by the bilateral importer	79.24	85.24	64.88	79.57	67.92	76.46
% of DVA 1st intermediate importer	CHN (4.05)	KOR (2.16)	CHN (6.38)	CHN (5.52)	CHN (9.54)	CHN (5.36)
% of DVA 2nd intermediate importer	KOR (2.33)	TWN (2.01)	KOR (2.82)	MEX (2.44)	KOR (3.29)	KOR (2.90)
% of DVA 3rd intermediate importer	SGP (1.82)	SGP (2)	DEU (2.41)	KOR (1.98)	USA (2.93)	SGP (2.12)
% of DVA 4th intermediate importer	TWN (1.73)	CHN (1.75)	SGP (2.37)	TWN (1.53)	THA (2.16)	THA (1.92)
% of DVA 5th intermediate importer	THA (1.41)	THA (1.45)	NLD (1.86)	USA (1.13)	TWN (1.88)	USA (1.46)
TAIWAN						
% of total gross export	100.00	70.10	8.47	13.49	1.13	6.82
% of total DVA absorbed by the market	100.00	55.56	12.65	19.78	2.04	9.97
% of DVA absorbed by the bilateral importer	72.36	85.21	49.07	59.27	49.46	60.70
% of DVA 1st intermediate importer	CHN (13.80)	CHN (5.58)	CHN (24.54)	CHN (24.26)	CHN (31.87)	CHN (21.47)
% of DVA 2nd intermediate importer	KOR (2.35)	KOR (2.11)	IRL (3.06)	MEX (2.48)	KOR (3.39)	KOR (2.87)

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Table 8. (*Continued*)

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of DVA 3rd intermediate importer	VNM (1.18)	SGP (1.03)	KOR (2.65)	KOR (2.45)	USA (2.20)	SGP (1.69)
% of DVA 4th intermediate importer	SGP (1.14)	MYS (0.99)	SGP (1.81)	VNM (1.73)	MEX (1.36)	VNM (1.46)
% of DVA 5th intermediate importer	MYS (1.10)	VNM (0.82)	DEU (1.76)	MYS (1.37)	VNM (1.34)	USA (1.39)
KOREA						
% of total gross export	100.00	55.99	12.66	16.87	2.08	12.39
% of total DVA absorbed by the market	100.00	45.24	15.01	21.88	2.79	15.07
% of DVA absorbed by the bilateral importer	78.26	86.72	64.22	71.00	71.34	78.56
% of DVA 1st intermediate importer	CHN (9.09)	CHN (4.37)	CHN (13.73)	CHN (14.45)	CHN (15.58)	CHN (9.65)
% of DVA 2nd intermediate importer	VNM (1.61)	VNM (1.38)	ROW (1.92)	MEX (3.48)	USA (1.70)	VNM (1.46)
% of DVA 3rd intermediate importer	MEX (1.00)	TWN (0.99)	VNM (1.88)	VNM (2.03)	MEX (1.46)	USA (0.99)
% of DVA 4th intermediate importer	USA (0.88)	SGP (0.74)	SVK (1.76)	USA (1.04)	VNM (1.36)	IND (0.69)
% of DVA 5th intermediate importer	ROW (0.83)	ROW (0.68)	USA (1.28)	JPN (0.85)	ROW (1.23)	JPN (0.68)
CHINA						
% of total gross export	100.00	31.58	20.49	28.52	4.11	15.29
% of total DVA absorbed by the market	100.00	27.13	21.31	30.20	4.44	16.91
% of DVA absorbed by the bilateral importer	85.58	89.22	79.49	85.81	88.58	86.18

Table 8. (*Continued*)

	World	Asia Pacific	Europe	NAFTA	Latin America	ROW
% of DVA 1st intermediate importer	MEX (1.38)	KOR (1.14)	DEU (1.98)	MEX (3.60)	USA (1.89)	KOR (1.54)
% of DVA 2nd intermediate importer	USA (1.35)	VNM (1.07)	ROW (1.84)	USA (1.24)	MEX (1.35)	USA (1.52)
% of DVA 3rd intermediate importer	KOR (1.25)	USA (1.05)	USA (1.63)	KOR (1.18)	KOR (1.09)	THA (0.77)
% of DVA 4th intermediate importer	ROW (0.94)	THA (1.04)	KOR (1.29)	VNM (0.98)	ROW (0.95)	VNM (0.76)
% of DVA 5th intermediate importer	VNM (0.91)	ROW (0.84)	FRA (0.90)	CAN (0.87)	VNM (0.52)	IND (0.73)
HONG KONG						
% of total gross export	100.00	58.76	16.19	9.58	0.62	14.85
% of total DVA absorbed by the market	100.00	56.16	16.58	12.00	0.93	14.34
% of DVA absorbed by the bilateral importer	83.69	90.63	68.41	73.81	53.50	84.38
% of DVA 1st intermediate importer	SGP (2.15)	SGP (1.93)	LUX (6.31)	CHN (4.77)	CHN (9.07)	CHN (2.2)
% of DVA 2nd intermediate importer	CHN (1.85)	CHN (0.85)	ROW (2.65)	SGP (2.57)	ROW (4.93)	SGP (2.07)
% of DVA 3rd intermediate importer	LUX (1.45)	ROW (0.81)	SGP (2.60)	ROW (2.03)	USA (3.41)	KOR (1.06)
% of DVA 4th intermediate importer	ROW (1.27)	TWN (0.77)	CHN (2.42)	KOR (1.48)	SGP (3.29)	LUX (1.01)
% of DVA 5th intermediate importer	KOR (0.90)	KOR (0.73)	GBR (2.03)	TWN (1.41)	KOR (2.63)	GBR (0.82)

Note: The results are based on the TiVA 2018 edition. In each case, total DVA of a country absorbed by a market corresponds to the sum of Components 1–3d. DVA absorbed by the bilateral importer corresponds to the sum of Components 1, 2a–2b, and 3c. The ranking of downstream partners is based on the amount of DVA that is intermediated by a trade partner before reaching third-country final destination markets (cf. Components 2c, 3a–3b, and 3d).

DVA destined for non-Asian markets passed through China. The structure in 2015 remained similar based on the TiVA tables of the 2018 edition, but with a downward revision in the level of reliance on China for all markets except Latin America.

Korea had a very similar export structure as Taiwan in 1995, both relying on China and the US as key downstream trade partners. In 2011, it also became more involved in the global value chain (in the sense that a higher fraction of its DVA absorbed abroad was intermediated rather than absorbed by bilateral importers), although the shift was less dramatic than Taiwan. China had become a dominating downstream trade partner of Korea by 2011, while Taiwan and Vietnam took the secondary intermediary role in 2011 and 2015, respectively.

The role China played as a key downstream trade partner to the economies discussed above (and others not reported) is also revealed by the extremely high fractions of its DVA absorbed by bilateral importers. This was 88.92% in 1995, with close to 1/3 of the remaining Chinese DVA intermediated by Hong Kong and the US before reaching its final destinations. The fraction of DVA absorbed by bilateral importers for China decreased to 84.57% in 2011 and 85.58% in 2015, but remained the highest among the set of economies studied. Over time, NAFTA became the most important market for the Chinese DVA, explaining the rising importance of Mexico and the US as its key downstream trade partners. This is in contrast with the diminished role of Hong Kong as its downstream intermediary.

Hong Kong had the second highest fraction of DVA absorbed by bilateral importers (next to China) throughout the period 1995–2015. Understandably, given its political and economic ties with China, the latter intermediated a dominant share of its remaining DVA destined for third countries. In recent years, however, Singapore has played an equally, if not more, important role in Hong Kong's downstream linkages. This was especially the case for Asia Pacific markets.

Singapore was also a relatively important downstream trade partner of Taiwan, Korea, and Japan in 1995, although its importance weakened over the years with respect to Korea. For Asia Pacific destination markets, however, Singapore continued to be a key downstream partner for the other Asian trading economies (except perhaps China).

4. How Much of Singapore's Exports are GVC Trade?

In this section, we characterize Singapore's participation in the GVC. As discussed in Section 1.1, several studies have proposed alternative measures of GVC participation. We highlight three of them. First, Hummels *et al.* (2001) proposed the Vertical Specialization (*VS*) index, which measures the fraction of imported inputs used in a country's gross exports. This original definition could in principle include the exporter's domestic contents re-imported. We modify the definition such that the *VS* index captures only the fraction of foreign contents (foreign value-added and foreign double-counted) in a country's gross exports. In a sense, this index captures the backward linkages of a country's involvement in the GVC. The larger the index, the more a country sources internationally for its production of gross exports. The subsequent literature typically used the sum of Components 7–9 in the KWW approach to construct the index.

Koopman *et al.* (2010) suggested to incorporate (in addition to foreign contents) the domestic contents in a country's gross exports that are not absorbed by bilateral importers. This includes domestic contents that are absorbed by third countries or that return home and are absorbed by the exporting country itself. The augmented measure GVC^{KWW} thus incorporates not only VS but also domestic contents that are involved in the GVC via forward linkages. This corresponds to the sum of Components 3–9 in the KWW approach.

As argued by BM, applying the above measures with the sink-based approach is not a clean way to ascertain GVC trade, as each component in Equation (1) contains all potential backward linkages (with the use of the global Leontief matrix **B**). In contrast, with the source-based approach, the decomposition in Equation (2) can identify the DVA components in a trade flow that cross national borders only once. These correspond to Components 1a* and 2a*. They can be regarded as the classic type of trade, in contrast with value-added flows involved in global value chains (which require more than one international shipment). Thus, a GVC index following BM can be constructed as follows:

$$GVC_s^{BM} = 1 - \sum_{r \neq s} (1a_{sr}^* + 2a_{sr}^*)/E_{s*}, \tag{4}$$

where $E_{s*} = \sum_{r \neq s} \mathbf{u}_G \mathbf{E}_{sr}$ is the aggregate gross exports of country *s*. We can also construct the corresponding *VS* measure and the GVC^{KWW} measure using the source-based approach as follows:

$$VS_s = \sum_{r \neq s} (7_{sr}^* + 8_{sr}^* + 9_{sr}^*)/E_{s*}, \tag{5}$$

$$GVC_s^{KWW} = \sum_{r \neq s} (3_{sr}^* + 4_{sr}^* + 5_{sr}^* + 6_{sr}^* + 7_{sr}^* + 8_{sr}^* + 9_{sr}^*)/E_{s*}. \tag{6}$$

Note the discussion in Section 2.1 about the caveats of the KWW decomposition. In particular, the assignments of DVA absorbed by the direct importer (Component 2) and by third countries (Component 3) in KWW are not exact, as the BM decomposition indicates that Component 2c is absorbed by third countries while 3c is absorbed by the bilateral importer. Thus, the GVC^{KWW} measure based on the KWW decomposition will be subject to this caveat.[5] Second, there is also discrepancy between KWW and BM in terms of their accounting of FVA and FDC (Components 9a–9b are considered part of double-counted foreign contents by KWW, when they are accounted for as FVA in BM). But since the *VS* measure is based on foreign contents (the sum of foreign value-added and foreign double-counted), whether one uses the KWW decomposition or the source-based BM decomposition should lead to the same results (subject to numerical approximation errors).

Tables 9–10 present the above measures for Singapore and the other major exporters, for the period 1995–2011 based on the TiVA 2016 edition and for the period 2005–2015 based on the TiVA 2018 edition, respectively. The comparison across periods is made difficult because of the discrete jump in the indices due to the changes in the underlying

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[5] Given the hindsight of the BM decomposition, one may construct the measure in a more precise way according to: $GVC_s^{KWW} = \sum_{r \neq s} (1c_{sr}^* + 2c_{sr}^* + 3a_{sr}^* + 3b_{sr}^* + 3d_{sr}^* + 4_{sr}^* + 5_{sr}^* + 6_{sr}^* + 7_{sr}^* + 8_{sr}^* + 9_{sr}^*)/E_{s*}$.

TiVA tables. During 1995–2011, foreign contents typically accounted for more than 40% of Singapore exports. Including Singapore domestic contents not absorbed by bilateral importers (according to the KWW decomposition) further increased the percentage to about 48%. The magnitudes of GVC^{KWW} turned out to be numerically similar whether the sink or the source-based approach was adopted. Using the most extensive measure, GVC^{BM} suggested that at least 52% of Singapore exports were GVC trade.

Japan had the lowest fraction of foreign contents in gross exports (6% in 1995) among this set of economies. Over the 1995–2011 period, its VS increased (15% in 2011) but remain the lowest compared with the other economies. This also holds for GVC^{KWW} and GVC^{BM}, although in recent years Japan became increasingly more involved in GVC in comparison with the US (another country with a low level of VS). In 2011, 40% of Japanese exports were GVC trade.

Taiwan and China have very similar profiles of participation in GVC (about 30–40% of the foreign contents and 40–50% of GVC trade). In more recent years, however, the trend of GVC slowed down in China but continued to intensify in Taiwan. Taiwan ranked lower than Singapore by the VS measure (foreign contents only), but rose to rival Singapore in 2005 by the GVC^{BM} measure (59% versus 56%), with all forward linkages included.

Korea started with a medium degree of participation in GVC (22% of foreign contents and 36% of GVC trade in 1995), but it reached a level of GVC involvement on a par with, if not more than, Singapore by 2011. In contrast with Singapore, Hong Kong had a very low fraction of foreign contents in its gross exports, with a GVC profile closer to that of Japan and the US than to the other Asian economies.

The results in Table 10 based on the TiVA 2018 edition suggest an even higher degree of GVC participation for Singapore during 2005–2015, when most other economies experienced a technical downward revision of the GVC measures, given the change of the TiVA tables. Notably, the downward revision for China was so substantial that it now swapped profiles with Hong Kong, and was ranked closer to the US and Japan among this set of economies. In sum, Singapore started off as a country with a very high level of GVC trade and has remained so, but its unique status has become gradually diluted over the years, with East Asian economies (such as Taiwan and Korea) making great strides in this direction.

4.1. *GVC participation at the regional level*

We now analyze how Singapore's participation in GVC may vary across regions. First, we look at Singapore's exports to countries in a certain region (such as NAFTA) and calculate how much of its regional exports are GVC-related trade. Section A of Table 11 summarizes the results for Singapore's GVC involvement at the regional level, based on the GVC^{BM} measure in Equation (4). The column "World" replicates the statistics reported in Tables 9 and 10 under the column GVC^{BM} for Singapore. Overall, Singapore's exports to Asia Pacific were more GVC-intensive than its exports to the other regions (50–60%). This was even more so for its exports to the subset of ASEAN countries (60–70%). Europe was another region to which Singapore's exports exhibited relatively high levels of integration in the GVC (50–60%). In contrast, more than half of Singapore's exports to Latin America and NAFTA were traditional trade.

Table 9. Participation in GVC, 1995–2011

	VS (%)	VS (Source) (%)	GVC^{KWW} (%)	GVC^{KWW} (Source) (%)	GVC^{BM} (Source) (%)	Downstreamness
SINGAPORE						
1995	42.06	42.06	47.84	47.84	52.37	0.80
2000	45.28	45.28	53.54	53.54	59.79	0.76
2005	39.76	39.76	48.54	48.54	55.70	0.71
2011	41.73	41.73	49.75	49.75	56.84	0.73
JAPAN						
1995	5.62	5.62	17.50	17.51	25.12	0.22
2000	7.40	7.40	21.84	21.84	30.75	0.24
2005	11.09	11.09	26.13	26.13	35.91	0.31
2011	14.70	14.70	29.38	29.38	40.01	0.37
TAIWAN						
1995	30.65	30.65	38.17	38.17	43.69	0.70
2000	32.21	32.21	42.28	42.28	49.08	0.66
2005	37.40	37.40	50.12	50.12	58.74	0.64
2011	43.51	43.51	54.41	54.41	62.44	0.70
KOREA						
1995	22.31	22.31	30.48	30.48	36.33	0.61
2000	29.68	29.68	39.51	39.51	46.18	0.64
2005	32.97	32.97	44.54	44.54	52.55	0.63
2011	41.63	41.63	50.96	50.96	57.91	0.72
CHINA						
1995	30.98	30.98	35.91	35.89	39.44	0.79
2000	35.93	35.93	41.31	41.31	45.00	0.80
2005	37.37	37.37	44.12	44.12	48.69	0.77
2011	32.11	32.11	40.15	40.15	45.52	0.71
HONG KONG						
1995	21.56	21.56	28.74	28.74	34.53	0.62
2000	15.55	15.55	25.72	25.72	33.85	0.46
2005	17.53	17.53	27.90	27.90	36.53	0.48
2011	20.41	20.41	29.99	29.99	38.30	0.53
USA						
1995	11.43	11.43	23.79	23.79	28.92	0.40
2000	12.52	12.52	28.61	28.61	34.11	0.37
2005	13.01	13.01	27.85	27.85	34.12	0.38
2011	14.97	14.97	28.19	28.19	35.52	0.42

Note: The calculations are based on the TiVA 2016 edition. The measures are defined in Equation (5) for *VS* (source), Equation (6) for GVC^{KWW} (source), and Equation (4) for GVC^{BM}. The corresponding measures for *VS* and GVC^{KWW} are based on the KWW decomposition. The downstreamness measure is defined in Equation (7) by VS/GVC^{BM} using the source-based statistics.

Table 10. Participation in GVC, 2005–2015

	VS (%)	VS (Source) (%)	GVC^{KWW} (%)	GVC^{KWW} (Source) (%)	GVC^{BM} (Source) (%)	Downstreamness
SINGAPORE						
2005	42.80	42.80	52.83	52.83	59.22	0.72
2011	43.52	43.52	53.04	53.05	58.64	0.74
2015	40.93	40.93	51.06	51.07	57.50	0.71
JAPAN						
2005	10.18	10.18	24.05	24.06	31.22	0.33
2011	14.30	14.30	28.17	28.19	34.85	0.41
2015	13.23	13.23	25.88	25.90	32.68	0.40
TAIWAN						
2005	37.12	37.12	48.86	48.88	55.59	0.67
2011	42.13	42.13	53.20	53.22	58.72	0.72
2015	32.42	32.42	44.57	44.59	52.03	0.62
KOREA						
2005	32.71	32.71	43.38	43.39	49.54	0.66
2011	42.42	42.42	51.04	51.06	55.63	0.76
2015	32.58	32.58	42.43	42.45	48.37	0.67
CHINA						
2005	26.27	26.27	34.93	34.93	39.68	0.66
2011	21.74	21.74	31.33	31.33	36.05	0.60
2015	17.32	17.32	27.81	27.81	32.72	0.53
HONG KONG						
2005	27.65	27.65	35.98	35.98	41.66	0.66
2011	32.36	32.36	39.68	39.69	44.50	0.73
2015	26.60	26.60	33.85	33.85	38.91	0.68
USA						
2005	10.76	10.76	24.77	24.79	29.91	0.36
2011	12.73	12.73	25.82	25.85	31.46	0.40
2015	9.48	9.48	22.90	22.93	28.15	0.34

Note: The calculations are based on the TiVA 2018 edition. The measures are defined in Equation (5) for *VS* (source), Equation (6) for GVC^{KWW} (source), and Equation (4) for GVC^{BM}. The corresponding measures for *VS* and GVC^{KWW} are based on the KWW decomposition. The downstreamness measure is defined in Equation (7) by *VS/GVC^{BM}* using the source-based statistics.

Next, we characterize the source of foreign contents in Singapore's gross exports. Section B of Table 11 indicates that Singapore relied heavily on countries in Asia Pacific as sources of foreign contents to produce its gross exports (30–50%), followed by country sources from Europe (20–30%) and then NAFTA (10–20%). ASEAN as a subset of Asia Pacific, however, played a less important role than either Europe or NAFTA (9–15%). This

Table 11. Decomposition of Singapore's Participation in GVC by Regions

A. Participation of Singapore in GVC by Regional Exports (GVC^{BM})

	World	Asia Pacific	ASEAN	Europe	NAFTA	Latin America	ROW
1995	52.37%	53.07%	56.87%	55.35%	51.61%	39.93%	45.74%
2000	59.79%	63.94%	71.27%	61.50%	50.52%	46.05%	54.06%
2005	55.70%	60.30%	64.35%	57.32%	41.32%	42.42%	48.38%
2011	56.84%	60.55%	64.63%	59.57%	42.72%	45.64%	48.29%
2005	59.22%	64.47%	71.91%	56.32%	45.55%	46.02%	50.58%
2011	58.64%	61.31%	67.14%	59.73%	47.17%	45.87%	51.64%
2015	57.50%	58.31%	64.24%	64.54%	44.77%	45.02%	52.53%

B. Origin of Foreign Contents in Gross Exports of Singapore (FC)

	World	Asia Pacific	ASEAN	Europe	NAFTA	Latin America	ROW
	(in $'000,000)	(in %)	(in %)	(in %)	(in %)	(in %)	(in %)
1995	36332.53	50.25	13.35	18.57	19.81	0.92	10.44
2000	45469.96	44.85	13.59	19.58	21.56	0.79	13.22
2005	51757.56	36.06	9.14	27.45	17.17	2.16	17.16
2011	115003.20	40.52	10.17	23.70	13.84	2.55	19.39
2005	60882.45	33.72	9.70	22.33	15.07	0.90	27.97
2011	130960.22	37.83	11.55	20.02	12.98	1.44	27.73
2015	123315.87	41.21	11.14	21.94	15.40	1.16	20.29

C. Bilateral Importer of Singapore Contents Net of Traditional Trade (DC–TT)

	World	Asia Pacific	ASEAN	Europe	NAFTA	Latin America	ROW
	(in $'000,000)	(in %)	(in %)	(in %)	(in %)	(in %)	(in %)
1995	8912.33	52.91	24.87	23.88	19.74	0.44	3.02
2000	14560.72	66.61	38.71	17.68	11.40	0.32	3.99
2005	20741.56	68.71	30.27	20.40	6.63	0.80	3.46
2011	41664.69	69.28	26.17	21.34	5.09	0.60	3.68
2005	23361.05	63.05	27.91	27.17	5.13	0.29	4.36
2011	45491.72	62.12	24.92	28.20	3.64	0.23	5.82
2015	49933.23	53.01	20.50	38.10	3.34	0.25	5.30

Note: The calculations are based on the TiVA 2016 edition for 1995–2011 and the TiVA 2018 edition for 2005–2015. Section A: The statistics presented are based on the GVC^{BM} measure defined in Equation (4), for Singapore's exports to the countries in each region. Section B: The column "World" indicates the value of foreign contents in Singapore's gross exports. The columns by region indicate the percentage of foreign contents (FC) originating from countries of the region. Section C: The column "World" indicates the value of Singapore contents net of traditional trade (DC–TT) in Singapore's gross exports. The columns by region indicate the percentage of Singapore's DC–TT intermediated by countries of the region.

suggests that Singapore's backward linkages were more strongly integrated with East Asian countries than with its regional neighbors.

Third, we can also look at how much each region imports Singapore's domestic contents and exports them after further processing. In other words, this measures how much of

Singapore's domestic content (net of traditional trade) is intermediated by a region. Section C of Table 11 suggests that more than half of Singapore's domestic contents were intermediated by the countries in Asia Pacific (50–70%), followed by Europe (20–40%) and NAFTA (3–20%). Over the years, however, Europe was taking on an increasingly larger weight in Singapore's forward linkages. In comparison to their role in Singapore's backward linkages, ASEAN countries were found to play a much more substantial role in Singapore's forward linkages (20–40%).

In sum, Singapore has been highly integrated with countries in the Asian regional production network, more so in forward linkages than in backward linkages. ASEAN, being an important political and economic association of the region, was critical in Singapore's forward linkages (intermediating Singapore's domestic contents absorbed in third countries), although much less so in Singapore's backward linkages.

5. Position of Singapore in the GVC

5.1. *Measures of downstreamness by Antràs and Chor (2018)*

As discussed in Section 1.1, Antràs *et al.* (2012), Fally (2012), and Miller and Temurshoev (2017) have proposed alternative measures of upstreamness and downstreamness. Antràs and Chor (2018) provided a summary of these measures. They are in essence calculated based on the Ghosh (inverse) matrix and the Leontief (inverse) matrix. Specifically, the upstreamness of a country-sector is measured by the total forward linkages of a country-sector, which equals the column sum of the Ghosh matrix for the row corresponding to the country-sector examined. On the other hand, the downstreamness is measured by the total backward linkages of a country-sector, which equals the row sum of the Leontief matrix for the column corresponding to the country-sector under study.

We provide such measurements for Singapore and the other economies in Tables A.3–A.5 for years 1995, 2011 and 2015 in the appendix. As indicated in these tables, when a country-sector is considered relatively upstream by the U_{AC} measure, it also tends to be considered downstream by the D_{AC} measure. The two measures are positively correlated in most cases. In fact, the weighted average (by sector output) or unweighted average of the U_{AC} measure across sectors for each country is very similar to that of D_{AC}. Thus, they are not informative indicators of the position of a country-sector in the global value chain. Rather, the positive correlation between the two measures suggests that when a country-sector is characterized as having intensive forward linkages, it also tends to have intensive backward linkages.

5.2. *Downstreamness by the distance to final demand*

In identifying countries' key downstream partners in the GVC, Tables 6–8 also report the percentage of DVA absorbed by bilateral importers as a byproduct. The residual of the index corresponds to the fraction of DVA that is further exported by bilateral importers and absorbed elsewhere. In this sense, we can regard the percentage of DVA absorbed by

bilateral importers as a country's closeness to final demand, and hence, a measure of downstreamness. The larger the fraction, the more downstream a country is.

We now characterize this index across years for the economies under study. The results are summarized in Figure 1 (for 1995–2011 based on the TiVA 2016 edition). The percentage of DVA absorbed by bilateral importers decreased overall between 1995 and 2011 for Singapore and the other major Asian exporters. The downward trend was especially pronounced in the case of Taiwan. This suggests that the DVA of these economies was going through more production stages across borders before reaching the final destinations.

China was the most downstream country in this set of economies (and in fact, in the world). The remaining five economies were relatively similar in terms of downstreamness until 2001, when Taiwan started to break away from the group and became increasingly more upstream, although the downward trend tended to moderate after 2008.

Across different destinations, these Asian exporters were the most distant from European destinations and closest to the regional Asian markets in terms of their positions in the value chain. Taiwan in particular was in a very upstream position for its DVA destined for Europe. Singapore's downstreamness was in the intermediate range among this group of economies on the whole, although its relative upstreamness compared to China was more pronounced for DVA destined to NAFTA than to the other markets. Hong Kong had a profile similar to Singapore in terms of closeness to final demand, although it tended to be more downstream than Singapore except noticeably for DVA destined for Latin America, for which market Hong Kong became substantially more upstream between 2006–2011.

The pattern in Figure 2 for 2005–2015 based on the TiVA 2018 edition are, in general, consistent with the observations made above. The exception is for the Latin American market, in which case Hong Kong now (without the dip in its trend) was also found to be more downstream than Singapore.

5.3. *Our preferred measure of downstreamness*

In this section, we propose an alternative index to measure a country *s*'s downstreamness, as follows:

$$D_s = \frac{FC_{s*}}{FC_{s*} + DC_{s*} - TT_{s*}} = \frac{VS_s}{GVC_s^{BM}}, \tag{7}$$

where FC_{s*} is country *s*'s foreign contents in its gross exports (to all destinations indicated by ∗), while $FC_{s*} + DC_{s*} - TT_{s*}$ is the country's GVC-related exports (i.e., gross exports net of traditional trade, TT_{s*}, while gross exports equal the sum of foreign contents, FC_{s*}, and domestic contents, DC_{s*}). We may regard FC_{s*} as country *s*'s backward linkages and $DC_{s*} - TT_{s*}$ as its forward linkages in the GVC. Thus, a country is considered relatively downstream if its GVC-related gross exports consist relatively more of backward linkages than forward linkages.

Note that the definition above (the fraction of foreign contents in a country's GVC-related gross exports) is equivalent to the ratio of the *VS* and GVC^{BM} indices
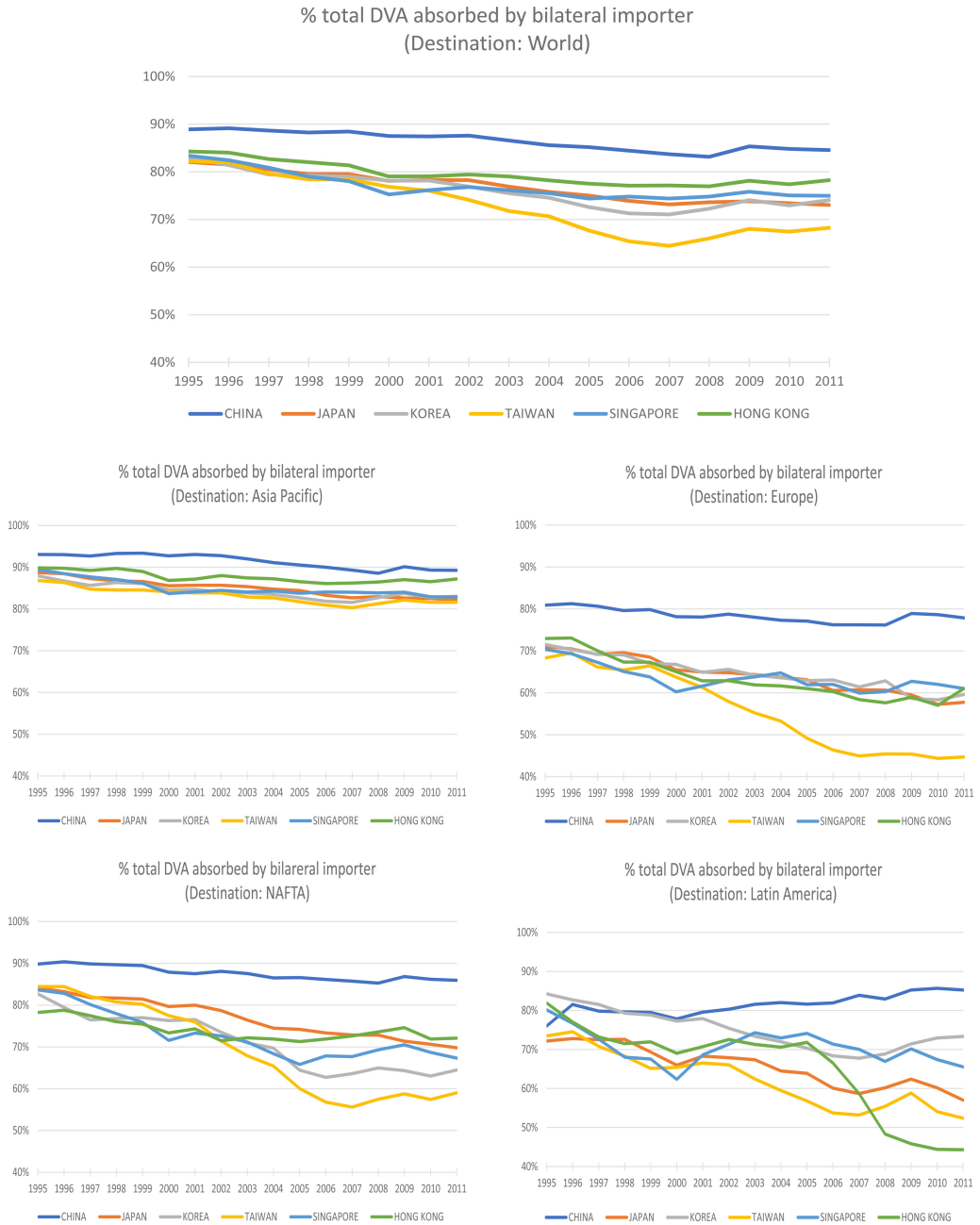
Figure 1. Closeness to Final Demand, 1995–2011

discussed in Section 4. Figures 3 and 4 illustrate the relative importance of the backward (*VS*) and forward (*GVC^{BM}–VS*) linkages for each country studied. The magnitudes *VS* and *GVC^{BM}* correspond to the source-based statistics reported in Tables 9 and 10. The downstreamness index for each country according to Equation (7) is summarized in the last column of these two tables.
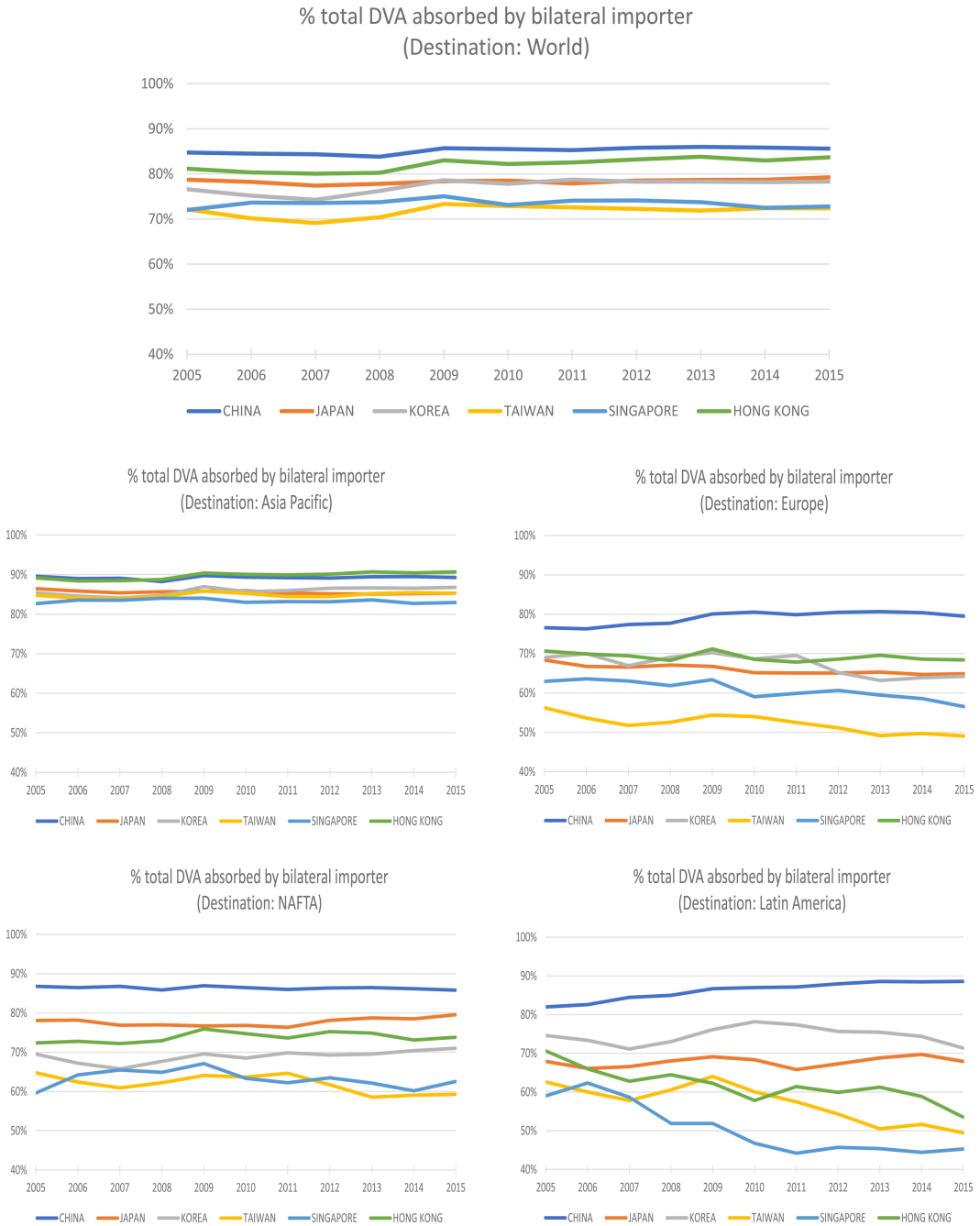
Figure 2. Closeness to Final Demand, 2005–2015

Of Singapore's exports involved in GVC trade, a dominant fraction was due to foreign contents (42% out of 52% in 1995 and 42% out of 57% in 2011). This corresponds to downstreamness indices of 0.80 and 0.73 in 1995 and 2011, respectively, the highest among the set of economies. In contrast, the proportion of foreign contents in Japan's GVC
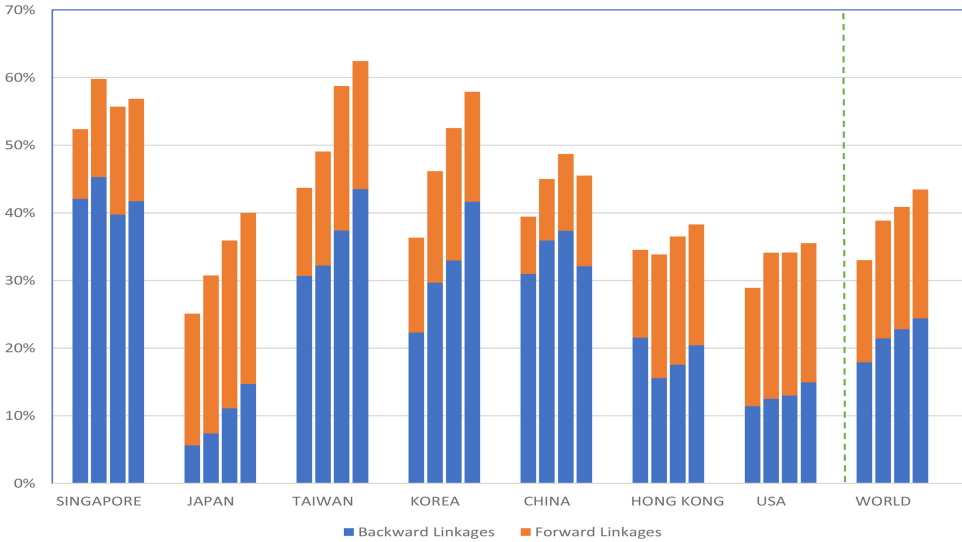
Figure 3. Backward linkages versus forward linkages in GVC Trade (1995–2011)

trade was substantially smaller (6% out of 25% in 1995 and 15% out of 40% in 2011), implying very low downstreamness indices of 0.22 and 0.37 in 1995 and 2011, respectively, the lowest among the set of economies. Singapore's downstreamness index
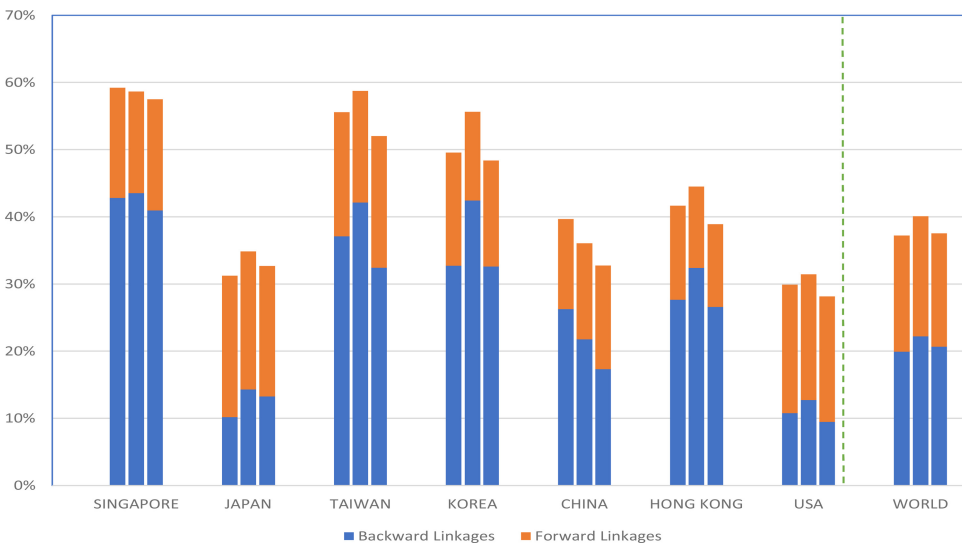
Figure 4. Backward linkages versus forward linkages in GVC Trade (2005–2015)

decreased over the years, but the country remained relatively downstream among the set of economies.

China was in the same league as Singapore, with its downstreamness index similar to Singapore's in 1995–2011. On the other hand, the US was positioned relatively upstream in the GVC (in the same league as Japan). Taiwan's deepening of GVC trade during 1995–2011, described in Section 4, was balanced between backward and forward linkages, with a relatively stable fraction of foreign contents in its total GVC trade. Korea started being more upstream than Taiwan, but the ranking gradually reversed over the years. Hong Kong had a GVC structure closer to Japan and the US, as indicated in Section 4. Its position was also located closer to these two economies and was more upstream than Korea and Taiwan. Between 1995 and 2011, Japan had moved more downstream. The US similarly did so, although at a slower pace. On the other hand, China's position moved upstream in the chains over the years (even though it was still on the relatively downstream side). Thus, the two large trading blocs (the US and China) became closer competitors in their GVC positions.

The trend indicated in Table 10 for 2005–2015 is in general consistent with the findings above, except for Hong Kong. In the TiVA 2018 edition, Hong Kong now was found to have a much more downstream position, pretty close to Korea and Taiwan. The opposite was the case for China, whose statistics exhibited a discontinuous shift from those based on the TiVA 2016 edition, implying a much more upstream position. Nonetheless, the same upward movement was observed for China in its GVC position during the period 2005–2015.

6. GVC Participation and Position at the Sector Level

In this section, we further characterize the participation and position of Singapore in the GVC at the sector level. Toward this, we use the BM decomposition framework and disaggregate gross exports by sector. Define the local Leontief matrix of country c in Equation (2) as $\tilde{\mathbf{B}}_{cc} \equiv (\mathbf{I} - \mathbf{A}_{cc})^{-1}$ for $c = s, t$. The decomposition of Equation (2) by sector of exports is obtained by expanding $\mathbf{V}_c\tilde{\mathbf{B}}_{cc}$ (a $1 \times G$ vector) to a $G \times G$ diagonal matrix with the value-added shares in final production (i.e., each element of $\mathbf{V}_c\tilde{\mathbf{B}}_{cc}$) placed along the principal diagonal and zeros elsewhere. Given this disaggregation, the same GVC^{BM} index in Equation (4) can be calculated for each export sector.

For example, Component 1a* of Singapore's exports of electronics includes Singapore's DVA from all its domestic sectors embodied in electronics exports (as Singapore's final goods) directly absorbed by the bilateral importer. Similarly, Component 2a* of Singapore's exports of electronics includes Singapore's DVA from all its domestic sectors embodied in electronics exports (as intermediate inputs for further processing in the bilateral importer) and absorbed by the bilateral importer as its local final goods/services. The remaining components consist of Singapore's domestic contents embodied in Singapore's exports of electronics not directly absorbed by bilateral importers, and foreign contents in Singapore's exports of electronics. The resulting GVC^{BM} index measures how much of Singapore's electronics exports are associated with GVC trade.

Tables 12 and 14 summarize the findings. We highlight in boldface the sectors whose percentages of GVC trade exceed the country average in the respective year, where the country average is as indicated in the Singapore section of Tables 9 and 10 under the column GVC^{BM}. The sector of coke, refined petroleum products and nuclear fuel was found to be the most GVC-intensive sector of Singapore in the period 1995–2011. Basic metals; computer, electronic and optical equipment; rubber and plastics products; and fabricated metals were also heavily involved in GVC trade. Chemicals and chemical products, and electrical machinery and apparatus, n.e.c., became more intensive, while motor vehicles declined in this regard over the years. Overall, manufacturing exports of Singapore were deeply intertwined in the global value chain. By the GVC^{BM} measure, it was as high as 85% for the sector of coke, refined petroleum products and nuclear fuel in 2011. The corresponding world average for the sector was 57%. Even service sectors of Singapore such as R&D and other business activities, and financial intermediation were found to be intensive in GVC trade (54% and 45% in 2011, respectively), much higher than the corresponding world average (43% and 37% in 2011) shown in Table 13. In comparison, the respective measures in 2011 were 35% and 32% for Japan, 46% and 18% for Taiwan, 36% and 25% for Korea, and 41% and 12% for China.[6]

The results for 2011–2015 based on the TiVA 2018 edition highlight similar sets of key sectors intensive in GVC participation, although the sector classifications are not exactly the same across the two editions. Notably, service sectors such as transportation and storage, and wholesale and retail trade, had risen in prominence in terms of GVC participation in 2015 compared to 1995.

Tables 15 and 16 report the downstreamness of the key sectors identified above for Singapore, in contrast with the world average during the periods 1995–2011 and 2011–2015, respectively. The service sectors are differentiated from the manufacturing sectors by colors. Note that the sector of computer, electronic and optical equipment in Singapore moved substantially upstream between 1995 and 2011; its downstream index decreased from 0.83 to 0.64. Meanwhile, the same sector in the world became more downstream and remained stable in its ranking across sectors (as the third most downstream sector). Computer related services in Singapore experienced similar, albeit less pronounced, structural changes (a drop in downstreamness index from 0.90 to 0.83 during 1995–2011) when the sector in the world became more downstream (0.48 to 0.53). The same observation applies to the sectors of motor vehicles and rubber and plastics products in Singapore, which moved upstream during 1995–2011 in contrast with the sectors' worldwide trend. On the other hand, the sector of basic metals in Singapore became more downstream (0.76 to 0.87), and at a rate faster than its counterpart in the world (0.46 to 0.53).

Given the change in sector classifications, the results in Table 16, based on the TiVA 2018 edition, are not exactly comparable to Table 15, based on the TiVA 2016 edition. If we restrict the comparison within the period 2011–2015, many sectors in Singapore were found to move gradually upstream. These include notably rubber and plastics products, and motor vehicles, trailers and semi-trailers; nonetheless, these two sectors in the world also

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[6] Authors' calculations for these economies are available upon request.

Table 12. Participation of Singapore in GVC by Sector, 1995–2011

Sector	Year 1995	Sector	Year 2000
07 Coke, refined petroleum products	**77.37%**	**07 Coke, refined petroleum products**	**81.42%**
16 Motor vehicles, trailers and semi-trailers	**66.43%**	**11 Basic metals**	**75.70%**
11 Basic metals	**65.42%**	**15 Electrical machinery and apparatus, nec**	**72.46%**
14 Computer, electronic and optical equipment	**63.41%**	**14 Computer, electronic and optical equipment**	**69.07%**
09 Rubber and plastics products	**59.47%**	**09 Rubber and plastics products**	**65.00%**
12 Fabricated metal products	**58.13%**	**12 Fabricated metal products**	**64.24%**
15 Electrical machinery and apparatus, nec	**57.43%**	**08 Chemicals and chemical products**	**62.70%**
02 Mining and quarrying	**56.14%**	**04 Textiles, textile products, leather and footwear**	**61.30%**
10 Other non-metallic mineral products	**55.79%**	**13 Machinery and equipment, nec**	**61.27%**
08 Chemicals and chemical products	**55.05%**	**02 Mining and quarrying**	**61.14%**
05 Wood and products of wood and cork	**54.43%**	**05 Wood and products of wood and cork**	**61.02%**
13 Machinery and equipment, nec	**53.42%**	10 Other non-metallic mineral products	58.47%
04 Textiles, textile products, leather and footwear	51.82%	28 Computer and related activities	58.14%
20 Construction	51.36%	03 Food products, beverages and tobacco	56.32%
03 Food products, beverages and tobacco	50.34%	20 Construction	54.98%
17 Other transport equipment	49.26%	18 Manufacturing nec, recycling	54.87%
28 Computer and related activities	48.79%	16 Motor vehicles, trailers and semi-trailers	53.89%
18 Manufacturing nec, recycling	47.78%	23 Transport and storage	53.46%
06 Pulp, paper, paper products, printing	45.82%	29 R&D and other business activities	50.78%
23 Transport and storage	45.12%	17 Other transport equipment	50.34%
29 R&D and other business activities	44.92%	06 Pulp, paper, paper products, printing	50.08%
19 Electricity, gas and water supply	43.89%	27 Renting of machinery and equipment	45.49%
01 Agriculture, hunting, forestry and fishing	37.73%	21 Wholesale and retail trade, repairs	43.84%
21 Wholesale and retail trade, repairs	35.41%	19 Electricity, gas and water supply	41.19%
27 Renting of machinery and equipment	35.17%	30 Public admin. and defense, compulsory social security	41.01%
25 Financial intermediation	32.80%	25 Financial intermediation	37.77%
24 Post and telecommunications	27.77%	01 Agriculture, hunting, forestry and fishing	37.60%

Table 12. (*Continued*)

Sector	Year 1995	Sector	Year 2000
33 Other community, social and personal services	26.78%	24 Post and telecommunications	36.75%
22 Hotels and restaurants	25.54%	22 Hotels and restaurants	32.06%
32 Health and social work	19.63%	33 Other community, social and personal services	29.90%
31 Education	12.48%	32 Health and social work	20.28%
26 Real estate activities	12.14%	31 Education	14.03%
30 Public admin. and defense, compulsory social security	..	26 Real estate activities	11.83%
34 Private households with employed persons	..	34 Private households with employed persons	..

Sector	Year 2005	Sector	Year 2011
02 Mining and quarrying	**67.39%**	**07 Coke, refined petroleum products**	**85.00%**
07 Coke, refined petroleum products	**66.18%**	**11 Basic metals**	**81.78%**
11 Basic metals	**64.31%**	**10 Other non-metallic mineral products**	**71.46%**
12 Fabricated metal products	**63.62%**	**15 Electrical machinery and apparatus, nec**	**65.69%**
08 Chemicals and chemical products	**62.84%**	**12 Fabricated metal products**	**64.20%**
14 Computer, electronic and optical equipment	**61.37%**	**19 Electricity, gas and water supply**	**63.58%**
15 Electrical machinery and apparatus, nec	**61.01%**	**08 Chemicals and chemical products**	**62.76%**
09 Rubber and plastics products	**60.34%**	**14 Computer, electronic and optical equipment**	**62.49%**
23 Transport and storage	**60.22%**	**04 Textiles, textile products, leather and footwear**	**59.68%**
05 Wood and products of wood and cork	**60.07%**	**09 Rubber and plastics products**	**59.13%**
10 Other non-metallic mineral products	**57.82%**	**02 Mining and quarrying**	**59.06%**
19 Electricity, gas and water supply	**57.62%**	**28 Computer and related activities**	**58.71%**
28 Computer and related activities	**56.88%**	**23 Transport and storage**	**57.72%**
30 Public admin. and defense, compulsory social security	**54.09%**	**13 Machinery and equipment, nec**	**57.59%**
04 Textiles, textile products, leather and footwear	**54.06%**	**06 Pulp, paper, paper products, printing**	**57.05%**
29 R&D and other business activities	**53.67%**	**16 Motor vehicles, trailers and semi-trailers**	**54.98%**
03 Food products, beverages and tobacco	**53.39%**	**29 R&D and other business activities**	**54.80%**
13 Machinery and equipment, nec	**53.01%**	**03 Food products, beverages and tobacco**	**54.24%**

Table 12. (*Continued*)

Sector	Year 2005	Sector	Year 2011
18 Manufacturing nec, recycling	50.83%	05 Wood and products of wood and cork	53.36%
16 Motor vehicles, trailers and semi-trailers	49.62%	18 Manufacturing nec, recycling	50.09%
06 Pulp, paper, paper products, printing	49.13%	24 Post and telecommunications	49.39%
21 Wholesale and retail trade, repairs	46.61%	30 Public admin. and defense, compulsory social security	47.79%
17 Other transport equipment	46.44%	17 Other transport equipment	46.88%
27 Renting of machinery and equipment	44.16%	20 Construction	46.13%
01 Agriculture, hunting, forestry and fishing	43.00%	25 Financial intermediation	45.41%
24 Post and telecommunications	41.34%	27 Renting of machinery and equipment	45.27%
20 Construction	41.33%	21 Wholesale and retail trade, repairs	44.94%
25 Financial intermediation	40.92%	01 Agriculture, hunting, forestry and fishing	43.20%
32 Health and social work	29.71%	31 Education	41.73%
33 Other community, social and personal services	29.60%	33 Other community, social and personal services	35.12%
22 Hotels and restaurants	29.24%	32 Health and social work	34.37%
31 Education	18.83%	22 Hotels and restaurants	33.25%
26 Real estate activities	13.73%	26 Real estate activities	33.18%
34 Private households with employed persons	..	34 Private households with employed persons	..

Note: The calculations are based on the TiVA 2016 edition. The GVC^{BM} measure defined in Equation (4) is applied to each sector of exports. Sectors with long descriptions are given below: 06 Pulp, paper, paper products, printing and publishing; 07 Coke, refined petroleum products and nuclear fuel. The GVC share for sectors with zero exports (of intermediates and final demand) in the data is indicated by the missing symbol "..".

Table 13. Participation in GVC by Sector (World), 1995–2011

Sector	Year 1995	Sector	Year 2011
11 Basic metals	**54.02%**	**11 Basic metals**	**64.00%**
09 Rubber and plastics	**44.77%**	**14 Computer, electronic and optical equipment**	**60.09%**
14 Computer, electronic and optical equipment	**44.31%**	**07 Coke, refined petroleum products**	**57.48%**
12 Fabricated metal products	**42.94%**	**09 Rubber and plastics products**	**57.03%**
15 Electrical machinery and apparatus, nec	**42.64%**	**15 Electrical machinery and apparatus, nec**	**55.10%**
08 Chemicals and chemical products	**42.04%**	**12 Fabricated metal products**	**53.70%**
16 Motor vehicles, trailers and semi-trailers	**40.18%**	**08 Chemicals and chemical products**	**53.12%**
07 Coke, refined petroleum products	**39.62%**	**16 Motor vehicles, trailers and semi-trailers**	**49.64%**
06 Pulp, paper, paper products, printing	**35.69%**	**19 Electricity, gas and water suppl**	**46.85%**
17 Other transport equipment	**34.81%**	**13 Machinery and equipment, nec**	**45.24%**
04 Textiles, textile products, leather and footwear	**33.67%**	**17 Other transport equipment**	**44.73%**
13 Machinery and equipment, nec	32.76%	29 R&D and other business activities	42.71%
29 R&D and other business activities	31.89%	06 Pulp, paper, paper products, printing	42.20%
05 Wood and products of wood and cork	31.36%	05 Wood and products of wood and cork	41.15%
19 Electricity, gas and water suppl	30.86%	10 Other non-metallic mineral products	40.74%
10 Other non-metallic mineral products	29.52%	23 Transport and storage	39.97%
18 Manufacturing nec, recycling	29.08%	02 Mining and quarrying	39.05%
02 Mining and quarrying	28.89%	18 Manufacturing nec, recycling	39.03%
23 Transport and storage	28.68%	25 Financial intermediation	37.46%
25 Financial intermediation	27.91%	04 Textiles, textile products, leather and footwear	36.93%
03 Food products, beverages and tobacco	24.50%	27 Renting of machinery and equipment	36.74%
20 Construction	24.43%	24 Post and telecommunications	35.62%
28 Computer and related activities	23.92%	28 Computer and related activities	35.35%
24 Post and telecommunications	23.84%	21 Wholesale and retail trade, repairs	31.16%
21 Wholesale and retail trade, repairs	23.54%	20 Construction	29.79%
01 Agriculture, hunting, forestry and fishing	23.02%	03 Food products, beverages and tobacco	29.50%
30 Public admin. and defense, compulsory social security	20.90%	30 Public admin. and defense, compulsory social security	29.14%

Table 13. (*Continued*)

Sector	Year 1995	Sector	Year 2011
27 Renting of machinery and equipment	20.87%	01 Agriculture, hunting, forestry and fishing	28.12%
33 Other community, social and personal services	16.03%	33 Other community, social and personal services	22.21%
32 Health and social work	13.76%	22 Hotels and restaurants	19.80%
22 Hotels and restaurants	11.00%	32 Health and social work	18.32%
31 Education	9.50%	31 Education	13.91%
26 Real estate activities	5.16%	26 Real estate activities	9.16%
34 Private households with employed persons	..	34 Private households with employed persons	..

Note: The calculations are based on the TiVA 2016 edition. The *GVC*^{BM} measure defined in Equation (4) is applied to each sector of exports. Sectors with long descriptions are given below: 06 Pulp, paper, paper products, printing and publishing; 07 Coke, refined petroleum products and nuclear fuel. The GVC share for sectors with zero exports (of intermediates and final demand) in the data is indicated by the missing symbol "..".

Table 14. Participation of Singapore in GVC by Sectors, 2011–2015

Sector	Year 2011	Sector	Year 2015
09 Coke and refined petroleum products	**88.56%**	**09 Coke and refined petroleum products**	**83.69%**
13 Basic metals	**68.67%**	**13 Basic metals**	**67.47%**
15 Computer, electronic and optical products	**66.09%**	**15 Computer, electronic and optical products**	**65.02%**
24 Transportation and storage	**63.44%**	**24 Transportation and storage**	**61.70%**
10 Chemicals and pharmaceutical products	**61.62%**	**10 Chemicals and pharmaceutical products**	**61.24%**
14 Fabricated metal products	**60.26%**	**16 Electrical equipment**	**60.22%**
12 Other non-metallic mineral products	58.03%	**12 Other non-metallic mineral products**	**59.92%**
11 Rubber and plastic products	57.64%	**14 Fabricated metal products**	**58.51%**
16 Electrical equipment	57.49%	23 Wholesale and retail trade, repair of motor vehicles	54.48%
21 Electricity, gas, water supply	56.93%	17 Machinery and equipment, nec	53.48%
17 Machinery and equipment, nec	55.09%	11 Rubber and plastic products	53.20%
22 Construction	53.12%	22 Construction	52.54%
08 Paper products and printing	51.44%	21 Electricity, gas, water supply	51.95%
19 Other transport equipment	48.57%	20 Other manufacturing	50.89%
07 Wood and products of wood and cork	48.29%	08 Paper products and printing	49.53%
32 Public admin. and defence, compulsory social security	47.03%	07 Wood and products of wood and cork	47.28%
23 Wholesale and retail trade, repair of motor vehicles	46.74%	26 Publishing, audiovisual and broadcasting activities	46.42%
05 Food products, beverages and tobacco	46.65%	05 Food products, beverages and tobacco	45.93%
20 Other manufacturing	46.27%	32 Public admin. and defence, compulsory social security	45.79%
18 Motor vehicles, trailers and semi-trailers	45.41%	18 Motor vehicles, trailers and semi-trailers	45.60%
26 Publishing, audiovisual and broadcasting activities	44.47%	29 Financial and insurance activities	45.28%
06 Textiles, wearing apparel, leather and related products	42.64%	19 Other transport equipment	44.72%
29 Financial and insurance activities	41.29%	06 Textiles, wearing apparel, leather and related products	43.70%
31 Other business sector services	39.69%	31 Other business sector services	41.79%
27 Telecommunications	38.60%	28 IT and other information services	40.74%
01 Agriculture, forestry and fishing	35.55%	27 Telecommunications	39.01%
28 IT and other information services	35.29%	01 Agriculture, forestry and fishing	35.87%

Table 14. (*Continued*)

Sector	Year 2011	Sector	Year 2015
25 Accommodation and food services	28.18%	25 Accommodation and food services	27.62%
30 Real estate activities	22.99%	35 Arts, entertainment, recreation and other services	23.39%
35 Arts, entertainment, recreation and other services	21.87%	30 Real estate activities	21.41%
34 Human health and social work	19.24%	34 Human health and social work	21.19%
33 Education	14.68%	33 Education	15.62%
02 Mining and extraction of energy producing products	..	02 Mining and extraction of energy producing products	..
03 Mining and quarrying of non-energy producing products	..	03 Mining and quarrying of non-energy producing products	..
04 Mining support service activities	..	04 Mining support service activities	..
36 Private households with employed persons	..	36 Private households with employed persons	..

Note: The calculations are based on the TiVA 2018 edition. The sector classifications are different from those of the TiVA 2016 edition. See Table A.2 for more details of the sector classifications. The GVC^{BM} measure defined in Equation (4) is applied to each sector of exports. Sectors with long descriptions are given below: 20 Other manufacturing, repair and installation of machinery and equipment; 21 Electricity, gas, water supply, sewerage, waste and remediation services; 35 Arts, entertainment, recreation and other service activities. The GVC share for sectors with zero exports (of intermediates and final demand) in the data is indicated by the missing symbol "..". The data for sectors 02–04 are not separately available for Singapore (rather than literally zeros).

Table 15. Downstreamness of Key Sectors in Singapore (1995–2011)

SINGAPORE		WORLD	
1995		**1995**	
25 Financial intermediation	0.51	02 Mining and quarrying	0.22
02 Mining and quarrying	0.62	29 R&D and other business activities	0.26
29 R&D and other business activities	0.64	25 Financial intermediation	0.28
09 Rubber and plastics products	0.71	23 Transport and storage	0.43
11 Basic metals	0.76	11 Basic metals	0.46
23 Transport and storage	0.76	28 Computer and related activities	0.48
15 Electrical machinery and apparatus, nec	0.80	09 Rubber and plastics products	0.52
12 Fabricated metal products	0.80	12 Fabricated metal products	0.53
14 Computer, electronic and optical equipment	0.83	15 Electrical machinery and apparatus, nec	0.60
28 Computer and related activities	0.90	14 Computer, electronic and optical equipment	0.64
07 Coke, refined petroleum products	0.91	07 Coke, refined petroleum products	0.66
16 Motor vehicles, trailers and semi-trailers	0.95	16 Motor vehicles, trailers and semi-trailers	0.70
2011		**2011**	
25 Financial intermediation	0.52	02 Mining and quarrying	0.15
02 Mining and quarrying	0.58	29 R&D and other business activities	0.28
29 R&D and other business activities	0.59	25 Financial intermediation	0.39
09 Rubber and plastics products	0.64	23 Transport and storage	0.50
14 Computer, electronic and optical equipment	0.64	28 Computer and related activities	0.53
12 Fabricated metal products	0.75	11 Basic metals	0.53
23 Transport and storage	0.77	09 Rubber and plastics products	0.56
15 Electrical machinery and apparatus, nec	0.80	12 Fabricated metal products	0.60
28 Computer and related activities	0.83	15 Electrical machinery and apparatus, nec	0.68
11 Basic metals	0.87	14 Computer, electronic and optical equipment	0.70
16 Motor vehicles, trailers and semi-trailers	0.88	16 Motor vehicles, trailers and semi-trailers	0.76
07 Coke, refined petroleum products	0.95	07 Coke, refined petroleum products	0.76

Note: The calculations are based on the TiVA 2016 edition. The statistics presented are based on Equation (7) calculated at the sector level. The service sectors are highlighted in color.

Table 16. Downstreamness of Key Sectors in Singapore (2011–2015)

SINGAPORE		WORLD	
2011		**2011**	
29 Financial and insurance activities	0.45	31 Other business sector services	0.31
31 Other business sector services	0.64	29 Financial and insurance activities	0.42
15 Computer, electronic and optical products	0.70	24 Transportation and storage	0.53
11 Rubber and plastic products	0.70	13 Basic metals	0.55
28 IT and other information services	0.70	11 Rubber and plastic products	0.60
13 Basic metals	0.72	10 Chemicals and pharmaceutical products	0.60
14 Fabricated metal products	0.73	14 Fabricated metal products	0.60
10 Chemicals and pharmaceutical products	0.74	28 IT and other information services	0.61
16 Electrical equipment	0.75	12 Other non-metallic mineral products	0.62
24 Transportation and storage	0.80	16 Electrical equipment	0.68
12 Other non-metallic mineral products	0.81	15 Computer, electronic and optical products	0.69
18 Motor vehicles, trailers and semi-trailers	0.89	18 Motor vehicles, trailers and semi-trailers	0.77
09 Coke and refined petroleum products	0.95	09 Coke and refined petroleum products	0.78
2015		**2015**	
29 Financial and insurance activities	0.44	31 Other business sector services	0.33
31 Other business sector services	0.65	29 Financial and insurance activities	0.43
11 Rubber and plastic products	0.67	13 Basic metals	0.50
15 Computer, electronic and optical products	0.68	24 Transportation and storage	0.53
16 Electrical equipment	0.75	14 Fabricated metal products	0.56

Table 16. (*Continued*)

SINGAPORE		WORLD	
14 Fabricated metal products	0.75	11 Rubber and plastic products	0.56
10 Chemicals and pharmaceutical products	0.76	10 Chemicals and pharmaceutical products	0.58
13 Basic metals	0.78	12 Other non-metallic mineral products	0.62
24 Transportation and storage	0.79	16 Electrical equipment	0.63
12 Other non-metallic mineral products	0.81	15 Computer, electronic and optical products	0.64
28 IT and other information services	0.82	28 IT and other information services	0.66
18 Motor vehicles, trailers and semi-trailers	0.86	18 Motor vehicles, trailers and semi-trailers	0.73
09 Coke and refined petroleum products	0.94	09 Coke and refined petroleum products	0.74

Note: The calculations are based on the TiVA 2018 edition. The sector classifications are different from those of the TiVA 2016 edition. See Table A.2 for more details of the sector classifications. The statistics presented are based on Equation (7) calculated at the sector level. The service sectors are highlighted in color.

Table 17. Significance of CPTPP to Singapore

YEAR: 1995	CPTPP	CPTPP+USA	CPTPP+CHN	CPTPP+CHN+USA
% of total gross export	26.64	48.48	29.98	51.82
% of total DVA absorbed by the market	26.30	47.97	28.85	50.52
% of DVA absorbed by the bilateral importer	86.13	85.99	86.10	85.98
% of DVA 1st intermediate importer	USA (4.0)	USA (2.2)	USA (3.8)	USA (2.17)
% of DVA 2nd intermediate importer	MYS (1.68)	MYS (1.99)	MYS (1.66)	MYS (1.97)
% of DVA 3rd intermediate importer	THA (1.12)	TWN (1.24)	THA (1.09)	TWN (1.29)
% of DVA 4th intermediate importer	CHN (0.98)	THA (1.14)	TWN (1.05)	THA (1.12)
% of DVA 5th intermediate importer	TWN (0.94)	CHN (1.1)	CHN (0.89)	CHN (1.05)
YEAR: 2011				
% of total gross export	23.60	33.35	35.88	45.63
% of total DVA absorbed by the market	20.15	34.41	30.47	44.74
% of DVA absorbed by the bilateral importer	79.51	75.38	76.97	74.61
% of DVA 1st intermediate importer	CHN (5.18)	CHN (6.86)	MYS (4.83)	CHN (5.23)
% of DVA 2nd intermediate importer	MYS (3.19)	MYS (3.79)	CHN (3.43)	MYS (4.76)
% of DVA 3rd intermediate importer	THA (1.68)	KOR (1.55)	KOR (2.17)	KOR (2.09)
% of DVA 4th intermediate importer	USA (1.55)	THA (1.52)	TWN (2.01)	TWN (1.93)
% of DVA 5th intermediate importer	KOR (1.29)	TWN (1.35)	THA (1.76)	THA (1.61)
YEAR: 2015				
% of total gross export	20.48	28.54	34.04	42.11
% of total DVA absorbed by the market	18.10	30.23	32.12	44.25
% of DVA absorbed by the bilateral importer	80.39	74.08	77.82	74.21
% of DVA 1st intermediate importer	CHN (3.42)	CHN (4.83)	MYS (3.20)	MYS (3.43)
% of DVA 2nd intermediate importer	IRL (2.23)	MYS (2.89)	KOR (2.40)	CHN (3.30)
% of DVA 3rd intermediate importer	MYS (2.12)	IRL (2.53)	TWN (2.16)	KOR (2.35)
% of DVA 4th intermediate importer	KOR (1.29)	KOR (1.67)	CHN (1.93)	TWN (2.03)
% of DVA 5th intermediate importer	THA (1.24)	THA (1.36)	IRL (1.62)	IRL (1.99)

Note: The calculations are based on the TiVA 2016 edition for years 1995 and 2011, and the TiVA 2018 edition for year 2015. Refer to the footnotes of Table 6.

experienced upward movement at a similar pace. On the other hand, several sectors in Singapore moved more downstream during the 2011–2015 period. The sector of IT and other information services saw a big increase in the downstreamness index (0.70 to 0.82), at a rate much faster than the world average. The sector of basic metals in Singapore continued its downward trend highlighted above (0.72 to 0.78), when the same sector in the world moved more upstream.

7. Importance of the CPTPP Free Trade Agreement

The Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) is a free trade agreement signed by 11 countries: Australia, Brunei Darussalam, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore and Vietnam. It was concluded in 2018 without the US after the Trump administration decided to withdraw from the agreement's predecessor TPP in 2017. Using the framework introduced in Section 3.2, we examine how important the CPTPP market is to Singapore and the counterfactual scenario if the US and/or China were to join the agreement.

Table 17 indicates that about one-quarter of Singapore's gross exports and DVA were absorbed by the CPTPP countries in 1995. The US would have been a critical CPTPP partner in 1995, as it accounted for another 22% of demand for Singapore's exports and value added. The US was also a key downstream trade partner of Singapore in serving the CPTPP countries (or the markets of the US and China). China played a relatively minor role at the time, whether in terms of size of final demand or as a downstream partner of Singapore.

The importance of the CPTPP market to Singapore declined to 20% in terms of DVA in 2011, and reduced further to 18% by 2015. Over the period 1995–2015, the relative importance of China rose. In 2011, it was comparable to the US in terms of market size for Singapore's exports. It also became the major downstream trade partner of Singapore for DVA destined to the CPTPP countries. By 2015, China had overtaken the US in terms of both markets for Singapore's exports and DVA. Overall, however, the combined group of CPTPP (with China and the US included) declined in terms of dominance in Singapore's export composition. In addition, some key downstream trade partners of Singapore (Taiwan, Korea, and Thailand) are not part of the CPTPP, when their inclusion would in principle bring about large benefits by streamlining the forward linkages of Singapore.

8. Conclusion and Policy Discussion

In summary, Singapore started off in 1995 as a country with a very high level of GVC trade, but its unique status became diluted over the years. East Asian economies (such as Taiwan and Korea) have become active players in GVCs in the last two decades. In contrast with Japan and the US, Singapore was generally located at the lower end of the GVC (with similar downstreamness index as China). Over the years, China, however, gradually moved upstream in the chains. Meanwhile, the US moved downstream. The narrowing gap in the GVC positions of the two giant trading blocs might help explain the rising trade tension and the technology race between the two countries.

In 1995, Japan, the US and Malaysia were the key upstream trade partners of Singapore, from which Singapore imported more than 45% of foreign contents associated with GVC trade. By 2011, China and India had risen significantly in the ranking, with the US and China being the most important upstream trade partners of Singapore. Nonetheless, Singapore had become more diversified in its sourcing, with a network of suppliers spread more evenly across regions and continents. In 1995, the US and Malaysia were also the most important downstream trade partners of Singapore; by 2011, China had replaced the US as the most important downstream trade partner of Singapore. The overlapping lists of Singapore's key upstream and downstream partners suggest there is no clear sequential order of the Asian economies in the value chain on aggregate. This may be because the relative upstreamness of these countries differs across products or because the global value chain of each product is not sequential but potentially roundabout.

Against the benchmark of Singapore's high level of participation in GVC in the aggregate, some of its manufacturing sectors were found to have particularly heavy involvement in the international production network. These include the sectors of coke, refined petroleum products and nuclear fuel; basic metals; computer, electronic and optical equipment; rubber and plastics products; and fabricated metals. Service sectors such as R&D and other business activities, and financial intermediation also had high levels of participation in GVC trade.

8.1. *Moving upstream?*

As highlighted in Section 5.3, Singapore is located at the very end of the GVC. This to some extent reflects its limited land area and natural resources. Hence, to produce goods for exports, it necessarily needs to import a high fraction of foreign inputs, raw materials, and components. This high dependence on foreign contents in manufacturing also spills over to the service sectors through domestic input–output linkages. For example, as indicated in Tables 15 and 16, the same service sectors (such as R&D and other business activities) are substantially more downstream in Singapore compared to the world average.

Conceptually, there is no definitive winning position in the GVC, although it might first appear to be preferable to be located upstream. Table A.6 provides the downstreamness statistics for a larger set of economies in the world. In 1995, Singapore, Mexico, Canada, Malaysia and Vietnam were located relatively downstream in the global value chains (similar to China), while Japan, Brunei, Peru and Australia were relatively upstream (similar to the US). Between 1995 and 2011, countries such as Brunei, Peru and Australia remained upstream, while Japan moved more downstream. Vietnam experienced the biggest changes, and became the most downstream country among the group in 2011. Malaysia similarly moved further downstream, although less dramatically than Vietnam.

As illustrated by Table A.6, countries located upstream can be those with comparative advantages in natural resources and primary commodities (such as Brunei and Brazil), or those with leading technology capacities (such as Japan and the US) that tend to provide the upstream services in product design, R&D, and key intermediate inputs. Countries located downstream also appear heterogeneous, with some specializing in lower-skilled

assembly activities (such as Malaysia, Mexico and Vietnam), while others focus on higher-skilled manufacturing/service activities (possibly Singapore, Taiwan and Canada).

Singapore has had a strong comparative advantage in the sectors of wholesale/retail service, finance/insurance, transportation/storage and other business services (as suggested by Ministry of Trade and Industry, 2011–2018). In the recent decade, service producing sectors typically accounted for 70% of its GDP. Most of these services are provided at the end of product value chains, hence partly explaining Singapore's downstream position. Its competitive advantage as an air freight and sea container transshipment hub and its well-established logistics infrastructure are likely to keep its future economy as an important player at the end segment of the GVC.

Nonetheless, as suggested by many initiatives, the Singaporean government has deemed it desirable to move up the value chains and engage in high-value manufacturing/service activities. For example, the report by iN2015 Manufacturing and Logistics Sub-Committee (2006) focuses on strengthening info-comm technologies of Singapore to facilitate its aims to be a supply chain nerve center and high value manufacturing hub. The government has also been proactive in attracting leading technology companies to locate their operations in Singapore (Leow, 2017), and with the hope of engaging in high-value activities that accompany manufacturing — from R&D and data analytics to intellectual property protection and logistics management. Alternative proposals have also envisaged factory-less manufacturing models where firms perform pre-production activities such as conceptualization, R&D, product design and engineering or development of specifications in Singapore, but outsource the actual production of the good to another country (Ministry of Trade and Industry, 2018).

As the economy matures and becomes one of the richest in the world, such structural changes will probably be mandatory (considering the aging population and rising production costs) and feasible (considering its abundant savings to finance the required investment in infrastructure, education and innovation capacity). In the process, Singapore is likely to gradually move toward both pre-production and post-production value-added activities, which may or may not translate into a definitive upward move of its position in the GVC on aggregate. As suggested by Tables 15 and 16, however, at the sector level, we did witness some significant upstream movements, for example in the computer, electronic and optical equipment sector, and computer related services, as well as the sectors of motor vehicles and rubber and plastics products during the period 1995–2015.

8.2. *FTA of Asia?*

Singapore has aggressively pursued free trade agreements, the CPTPP being a prominent example, in parallel with its multilateral obligations under the WTO. The current CPTPP formation is not self-contained, however, since Singapore's value-added destined to CPTPP countries passes through some key trade partners not included in the CPTPP. These include China, the US, Korea, Taiwan and Thailand. Despite the absence of the US from the group, its importance is not irreplaceable; China plays an almost equivalent role in terms of market size for Singapore's gross exports and value added. In either scenario of

enlargement with the US or China, Korea, Taiwan and Thailand are three key trade partners that intermediate Singapore's value added to the CPTPP+USA or CPTPP+China market (but excluded from the group). In Section 4.1, Asia Pacific as a whole was also found to be dominant in Singapore's backward and forward linkages. Seen from the global value chain perspective, an initiative that includes major exporting economies in Asia would create large gains from trade for Singapore by helping to streamline cross-border production arrangements. The Free Trade Area of the Asia Pacific, as proposed by the APEC, thus appears to be a promising proposal to improve the status quo toward an integrated production network across Asia.

Acknowledgments

Appendix

Table A.1. Country Groupings used in the Paper

Grouping	Countries
ASIA PACIFIC (16)	Australia, Brunei, Cambodia, China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, Taiwan, Thailand, Vietnam
EUROPE (33)	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungry, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Ro-mania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom
NAFTA (3)	Canada, Mexico, United States
LATIN AMERICA (6)	Argentina, Brazil, Chile, Colombia, Costa Rica, Peru
ROW (6)	Israel, Morocco, Saudi Arabia, South Africa, Tunisia, Rest of the World; Kazakhstan (singled out as a separate entity in TiVA 2018 edition)
ASEAN	Brunei, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam
CPTPP	Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, Vietnam

Note: Included are 63 economies in the TiVA 2016 edition, and 64 in the TiVA 2018 edition, in addition to a residual entity for the Rest of the World.

Table A.2. Sector Classifications of TiVA Tables

		TiVA 2016 Edition			TiVA 2018 Edition
Sector	TiVA Code	Description	Sector	TiVA Code	Description
1	C01T05AGR	Agriculture, hunting, forestry and fishing	1	D01T03	Agriculture, forestry and fishing
2	C10T14MIN	Mining and quarrying	2	D05T06	Mining and extraction of energy producing products
3	C15T16FOD	Food products, beverages and tobacco	3	D07T08	Mining and quarrying of non-energy producing products
4	C17T19TEX	Textiles, textile products, leather and footwear	4	D09	Mining support service activities
5	C20WOD	Wood and products of wood and cork	5	D10T12	Food products, beverages and tobacco
6	C21T22PAP	Pulp, paper, paper products, printing and publishing	6	D13T15	Textiles, wearing apparel, leather and related products
7	C23PET	Coke, refined petroleum products and nuclear fuel	7	D16	Wood and products of wood and cork
8	C24CHM	Chemicals and chemical products	8	D17T18	Paper products and printing
9	C25RBP	Rubber and plastics products	9	D19	Coke and refined petroleum products
10	C26NMM	Other non-metallic mineral products	10	D20T21	Chemicals and pharmaceutical products
11	C27MET	Basic metals	11	D22	Rubber and plastic products
12	C28FBM	Fabricated metal products	12	D23	Other non-metallic mineral products
13	C29MEQ	Machinery and equipment, nec	13	D24	Basic metals
14	C30T33XCEQ	Computer, Electronic and optical equipment	14	D25	Fabricated metal products
15	C31ELQ	Electrical machinery and apparatus, nec	15	D26	Computer, electronic and optical products
16	C34MTR	Motor vehicles, trailers and semi-trailers	16	D27	Electrical equipment
17	C35TRQ	Other transport equipment	17	D28	Machinery and equipment, nec
18	C36T37OTM	Manufacturing nec; recycling	18	D29	Motor vehicles, trailers and semi-trailers
19	C40T41EGW	Electricity, gas and water supply	19	D30	Other transport equipment
20	C45CON	Construction	20	D31T33	Other manufacturing; repair and installation of machinery and equipment
21	C50T52WRT	Wholesale and retail trade; repairs	21	D35T39	Electricity, gas, water supply, sewerage, waste and remediation services

Table A.2. (*Continued*)

	TiVA 2016 Edition			TiVA 2018 Edition	
Sector	TiVA Code	Description	Sector	TiVA Code	Description
22	C55HTR	Hotels and restaurants	22	D41T43	Construction
23	C60T63TRN	Transport and storage	23	D45T47	Wholesale and retail trade; repair of motor vehicles
24	C64PTL	Post and telecommunications	24	D49T53	Transportation and storage
25	C65T67FIN	Financial intermediation	25	D55T56	Accommodation and food services
26	C70REA	Real estate activities	26	D58T60	Publishing, audiovisual and broadcasting activities
27	C71RMQ	Renting of machinery and equipment	27	D61	Telecommunications
28	C72ITS	Computer and related activities	28	D62T63	IT and other information services
29	C73T74OBZ	R&D and other business activities	29	D64T66	Financial and insurance activities
30	C75GOV	Public admin. and defence; compulsory social security	30	D68	Real estate activities
31	C80EDU	Education	31	D69T82	Other business sector services
32	C85HTH	Health and social work	32	D84	Public admin. and defence; compulsory social security
33	C90T93OTS	Other community, social and personal services	33	D85	Education
34	C95PVH	Private households with employed persons	34	D86T88	Human health and social work
			35	D90T96	Arts, entertainment, recreation and other service activities
			36	D97T98	Private households with employed persons

Table A.3. GVC Position in 1995 by the Measures of Antràs and Chor (2018)

Sector	Description	SINGAPORE			JAPAN			TAIWAN			KOREA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
1	Agriculture, hunting, forestry and fishing	31	6.553	1.658	11	3.742	2.690	2	3.975	1.664	2	3.767	1.591
2	Mining and quarrying	28	3.457	3.170	2	3.367	1.892	11	3.456	2.937	11	3.760	3.161
3	Food products, beverages and tobacco	2	3.287	2.027	6	3.269	2.062	8	3.297	2.738	6	3.100	2.379
4	Textiles, textile products, leather and footwear	7	3.130	2.820	8	2.765	2.241	27	3.122	1.710	8	3.043	2.650
5	Wood and products of wood and cork	29	3.102	2.253	29	2.753	1.658	6	3.041	2.666	19	2.933	1.876
6	Pulp, paper products, printing and publishing	24	3.040	2.096	5	2.693	2.251	7	2.989	2.012	9	2.921	2.672
7	Coke, refined petroleum products and nuclear fuel	11	3.001	2.730	9	2.628	2.304	29	2.972	1.911	29	2.846	1.610
8	Chemicals and chemical products	19	2.997	2.615	27	2.603	1.560	9	2.948	2.615	7	2.809	2.395
9	Rubber and plastics products	8	2.974	2.447	10	2.421	1.989	12	2.876	2.690	5	2.738	2.451
10	Other non-metallic mineral products	6	2.930	2.171	12	2.420	2.269	19	2.737	1.872	27	2.716	1.538
11	Basic metals	9	2.875	2.498	25	2.410	1.577	10	2.656	2.434	10	2.705	2.344
12	Fabricated metal products	23	2.839	2.443	7	2.356	1.828	5	2.652	2.471	12	2.671	2.820
13	Machinery and equipment, nec	27	2.724	2.050	19	2.241	1.741	28	2.592	1.883	24	2.561	1.629
14	Computer, Electronic and optical equipment	5	2.682	2.615	18	2.236	2.451	26	2.573	1.418	25	2.559	1.641
15	Electrical machinery and apparatus, nec	21	2.576	1.984	1	2.147	1.834	31	2.392	1.309	28	2.538	1.951
16	Motor vehicles, trailers and semi-trailers	14	2.549	3.052	21	2.083	1.598	17	2.280	2.703	21	2.279	1.690
17	Other transport equipment	12	2.543	2.722	24	2.081	1.435	14	2.263	2.806	14	2.237	2.613
18	Manufacturing nec; recycling	15	2.490	2.703	28	2.041	1.682	15	2.189	2.921	22	2.216	2.146
19	Electricity, gas and water supply	10	2.489	2.617	16	1.975	2.776	21	2.152	1.501	1	2.089	1.677
20	Construction	26	2.152	1.537	14	1.896	2.289	1	2.114	2.091	26	1.967	1.508
21	Wholesale and retail trade; repairs	13	2.106	2.559	17	1.842	2.429	23	2.022	1.891	4	1.903	2.692
22	Hotels and restaurants	17	2.059	2.524	23	1.806	1.501	4	1.992	2.699	13	1.836	2.813
23	Transport and storage	32	2.049	1.966	13	1.727	2.300	13	1.909	2.856	16	1.765	2.900
24	Post and telecommunications	25	2.046	1.597	15	1.688	2.226	24	1.735	1.162	18	1.711	2.518
25	Financial intermediation	4	2.003	2.574	22	1.615	1.970	18	1.730	2.569	3	1.692	2.578
26	Real estate activities	1	1.840	2.172	4	1.566	2.181	16	1.594	2.927	17	1.666	2.690
27	Renting of machinery and equipment	33	1.674	2.210	3	1.435	2.164	3	1.583	2.504	15	1.644	2.805

Table A.3. (*Continued*)

Sector	Description	SINGAPORE			JAPAN			TAIWAN			KOREA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
28	Computer and related activities	18	1.618	2.549	33	1.367	1.591	33	1.305	1.866	23	1.640	1.480
29	R&D and other business activities	3	1.547	2.650	26	1.225	1.244	30	1.282	1.735	33	1.442	1.740
30	Public admin. and defence; compulsory social security	16	1.456	2.875	20	1.195	2.065	22	1.276	1.839	31	1.430	1.321
31	Education	20	1.314	2.754	32	1.072	1.861	20	1.249	2.544	32	1.233	1.796
32	Health and social work	22	1.210	2.161	30	1.033	1.578	25	1.175	1.475	20	1.170	2.229
33	Other community, social and personal services	30	1.168	2.376	31	1.021	1.213	32	1.118	1.926	30	1.000	1.690
34	Private households with employed persons	34	1.000	1.000	34	1.000	1.000	34	1.000	1.000	34	1.000	1.000
	Correlation			**−0.019**			**0.399**			**0.215**			**0.228**
	Unweighted average		**2.455**	**2.358**		**2.050**	**1.925**		**2.243**	**2.157**		**2.223**	**2.135**
	Weighted average		**2.377**	**2.442**		**1.900**	**1.879**		**2.134**	**2.167**		**2.115**	**2.179**

Sector	Description	CHINA			HONG KONG			USA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
1	Agriculture, hunting, forestry and fishing	2	4.048	2.243	11	3.313	2.858	11	3.504	2.506
2	Mining and quarrying	11	3.794	2.968	2	3.272	1.891	2	3.169	1.839
3	Food products, beverages and tobacco	19	3.599	2.264	7	2.808	2.032	5	2.795	2.462
4	Textiles, textile products, leather and footwear	6	3.581	3.044	29	2.719	1.565	12	2.782	2.177
5	Wood and products of wood and cork	7	3.465	2.843	8	2.714	2.432	9	2.618	2.357
6	Pulp, paper, paper products, printing and publishing	8	3.448	2.771	5	2.709	2.425	10	2.587	2.068
7	Coke, refined petroleum products and nuclear fuel	9	3.390	2.939	9	2.633	2.448	8	2.520	2.256
8	Chemicals and chemical products	25	3.180	1.666	6	2.513	2.303	1	2.443	2.225
9	Rubber and plastics products	12	3.038	2.966	12	2.451	2.707	6	2.426	2.219
10	Other non-metallic mineral products	5	2.932	2.823	27	2.431	1.296	29	2.390	1.607
11	Basic metals	23	2.911	2.069	19	2.167	1.406	13	2.376	2.324
12	Fabricated metal products	28	2.876	2.573	10	2.108	2.430	27	2.351	1.490

Table A.3. (*Continued*)

		CHINA			HONG KONG			USA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
13	Machinery and equipment, nec	24	2.818	2.137	15	1.995	2.457	23	2.303	1.946
14	Computer, Electronic and optical equipment	16	2.483	3.147	1	1.974	2.092	14	2.257	2.351
15	Electrical machinery and apparatus, nec	4	2.480	3.140	14	1.952	2.688	15	2.210	2.257
16	Motor vehicles, trailers and semi-trailers	21	2.464	2.051	24	1.807	1.571	7	2.193	2.377
17	Other transport equipment	10	2.440	2.643	16	1.728	1.888	28	2.090	1.539
18	Manufacturing nec; recycling	15	2.384	3.062	4	1.723	2.454	21	2.020	1.645
19	Electricity, gas and water supply	29	2.369	1.908	28	1.694	1.756	24	2.006	1.584
20	Construction	13	2.251	2.998	21	1.681	1.598	19	1.917	1.582
21	Wholesale and retail trade; repairs	1	2.198	1.894	23	1.645	1.420	25	1.916	1.650
22	Hotels and restaurants	17	2.175	3.152	3	1.589	2.157	16	1.837	2.763
23	Transport and storage	14	2.107	2.739	13	1.578	2.636	17	1.790	2.427
24	Post and telecommunications	22	2.049	2.335	25	1.566	1.314	18	1.612	2.195
25	Financial intermediation	26	1.912	1.369	18	1.528	2.440	33	1.597	1.766
26	Real estate activities	33	1.822	2.534	26	1.419	1.163	4	1.597	2.387
27	Renting of machinery and equipment	3	1.791	2.375	17	1.377	1.866	3	1.552	2.491
28	Computer and related activities	18	1.493	1.977	33	1.372	1.692	26	1.446	1.464
29	R&D and other business activities	27	1.193	1.722	22	1.275	1.878	22	1.383	2.031
30	Public admin. and defence; compulsory social security	31	1.178	2.137	31	1.163	1.274	20	1.255	2.109
31	Education	32	1.085	2.479	20	1.155	2.072	31	1.191	1.437
32	Health and social work	20	1.074	2.883	30	1.155	1.320	30	1.143	1.777
33	Other community, social and personal services	30	1.000	2.238	32	1.087	1.316	32	1.039	1.678
34	Private households with employed persons	34	1.000	1.000	34	1.000	1.000	34	1.000	1.000
	Correlation			**0.356**			**0.480**			**0.397**
	Unweighted average		**2.412**	**2.444**		**1.921**	**1.937**		**2.039**	**2.000**
	Weighted average		**2.473**	**2.525**		**1.622**	**1.616**		**1.848**	**1.884**

Note: The calculations are based on the TiVA 2016 edition. The first two columns provide the sector index and description. See Table A.2 for more details of the sector classifications. For each country, the sectors are ranked by the upstreamness measure U_{AC}. The correlation statistics provide the correlation between the two measures, U_{AC} and D_{AC}, across sectors. The average statistics refer to the average of each measure across sectors. The weighted average is weighted by the sector output.

Table A.4. GVC position in 2011 by the Measures of Antràs and Chor (2018).

Sector	Description	SINGAPORE			JAPAN			TAIWAN			KOREA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
1	Agriculture, hunting, forestry and fishing	8	3.473	2.847	2	16.063	2.113	11	3.920	3.512	11	4.136	3.528
2	Mining and quarrying	19	3.374	2.349	11	4.444	3.410	8	3.776	3.197	8	3.811	3.257
3	Food products, beverages and tobacco	11	3.372	2.413	6	3.163	2.033	6	3.437	2.906	7	3.405	2.582
4	Textiles, textile products, leather and footwear	27	3.335	2.094	8	3.085	2.707	7	3.290	2.406	9	3.387	3.087
5	Wood and products of wood and cork	2	3.277	1.960	9	2.781	2.575	2	3.222	2.353	2	3.303	2.041
6	Pulp, paper, paper products, printing and publishing	29	3.261	2.162	10	2.737	2.114	19	3.183	2.347	29	3.300	1.841
7	Coke, refined petroleum products and nuclear fuel	6	3.256	2.236	5	2.735	2.265	29	3.169	1.799	5	3.297	2.898
8	Chemicals and chemical products	9	3.240	2.542	29	2.728	1.575	9	3.104	3.070	19	3.231	2.349
9	Rubber and plastics products	7	3.183	3.028	12	2.669	2.577	5	2.902	2.738	6	3.144	2.736
10	Other non-metallic mineral products	21	3.147	1.936	27	2.589	1.422	10	2.816	2.630	10	3.142	2.677
11	Basic metals	10	3.096	2.315	7	2.478	2.238	12	2.814	3.165	12	3.016	3.180
12	Fabricated metal products	24	3.095	2.166	19	2.366	2.125	14	2.751	2.917	15	2.944	3.167
13	Machinery and equipment, nec	12	3.078	2.735	18	2.362	2.485	21	2.533	1.493	21	2.882	1.953
14	Computer, Electronic and optical equipment	14	2.906	3.033	21	2.302	1.712	15	2.419	3.181	14	2.846	3.208
15	Electrical machinery and apparatus, nec	28	2.875	3.077	1	2.284	2.095	27	2.392	1.797	28	2.752	2.120
16	Motor vehicles, trailers and semi-trailers	15	2.858	2.851	15	2.284	2.601	25	2.327	1.505	24	2.706	2.282
17	Other transport equipment	5	2.825	2.360	28	2.211	1.578	4	2.199	2.993	27	2.701	1.898
18	Manufacturing nec; recycling	23	2.694	2.448	16	2.194	3.089	13	2.121	3.244	25	2.560	1.701
19	Electricity, gas and water supply	13	2.564	2.749	14	2.182	2.492	17	2.004	3.120	13	2.343	3.216
20	Construction	1	2.534	1.962	24	1.917	1.756	1	1.938	2.288	16	2.343	3.452
21	Wholesale and retail trade; repairs	17	2.148	2.505	17	1.892	2.544	28	1.786	1.820	23	2.341	2.036
22	Hotels and restaurants	16	2.078	2.582	13	1.867	2.587	33	1.720	2.032	1	2.281	2.116
23	Transport and storage	18	2.011	2.470	23	1.853	1.529	16	1.719	3.193	18	2.193	3.088
24	Post and telecommunications	3	1.990	2.670	25	1.777	1.513	24	1.678	1.457	17	2.050	3.150
25	Financial intermediation	20	1.914	3.062	22	1.627	2.076	23	1.632	1.568	4	1.994	2.894
26	Real estate activities	26	1.831	1.553	4	1.588	2.287	3	1.579	2.767	26	1.780	1.580
27	Renting of machinery and equipment	33	1.624	2.072	3	1.542	2.229	26	1.528	1.398	3	1.768	2.957

Table A.4. (*Continued*)

Sector	Description	SINGAPORE			JAPAN			TAIWAN			KOREA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
28	Computer and related activities	4	1.564	2.736	33	1.369	1.604	22	1.506	2.066	33	1.614	2.187
29	R&D and other business activities	25	1.555	1.299	20	1.269	2.094	18	1.351	2.874	32	1.167	2.056
30	Public admin. and defence; compulsory social security	31	1.550	1.665	26	1.214	1.288	20	1.334	2.851	20	1.158	2.740
31	Education	32	1.487	2.023	31	1.043	1.361	32	1.239	1.858	30	1.146	1.760
32	Health and social work	22	1.463	2.154	30	1.036	1.611	30	1.181	1.558	22	1.104	2.628
33	Other community, social and personal services	30	1.318	2.296	32	1.030	1.858	31	1.106	1.442	31	1.085	1.518
34	Private households with employed persons	34	1.000	1.000	34	1.000	1.000	34	1.000	1.000	34	1.000	1.000
	Correlation			**0.397**			**0.188**			**0.490**			**0.427**
	Unweighted average		**2.499**	**2.334**		**2.520**	**2.075**		**2.255**	**2.369**		**2.469**	**2.496**
	Weighted average		**2.453**	**2.274**		**2.010**	**1.993**		**2.411**	**2.352**		**2.580**	**2.651**

Sector	Description	CHINA			HONG KONG			USA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
1	Agriculture, hunting, forestry and fishing	2	4.508	2.491	11	3.538	3.738	11	3.486	2.903
2	Mining and quarrying	19	4.320	3.078	7	3.238	2.151	2	3.123	1.882
3	Food products, beverages and tobacco	7	3.931	2.882	29	3.154	2.155	5	2.732	2.426
4	Textiles, textile products, leather and footwear	5	3.890	3.279	2	3.076	2.229	12	2.717	2.434
5	Wood and products of wood and cork	9	3.887	3.527	9	3.056	2.462	27	2.525	1.589
6	Pulp, paper, paper products, printing and publishing	11	3.798	3.555	6	2.841	2.513	10	2.513	2.256
7	Coke, refined petroleum products and nuclear fuel	6	3.797	3.227	27	2.799	1.610	9	2.504	2.409
8	Chemicals and chemical products	8	3.758	3.127	12	2.724	3.548	8	2.444	2.333
9	Rubber and plastics products	12	3.545	3.090	5	2.701	2.646	1	2.413	2.202
10	Other non-metallic mineral products	25	3.201	1.804	23	2.520	2.111	29	2.412	1.572
11	Basic metals	29	3.028	2.805	8	2.476	2.781	6	2.391	2.224
12	Fabricated metal products	27	2.991	3.016	19	2.365	1.740	13	2.375	2.451

Table A.4. (*Continued*)

		CHINA			HONG KONG			USA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
13	Machinery and equipment, nec	23	2.914	2.218	15	2.361	2.835	28	2.266	1.683
14	Computer, Electronic and optical equipment	21	2.906	1.909	28	2.354	1.879	23	2.252	1.885
15	Electrical machinery and apparatus, nec	1	2.850	2.057	10	2.253	2.808	14	2.107	1.759
16	Motor vehicles, trailers and semi-trailers	28	2.747	2.823	21	2.175	1.816	7	2.098	2.342
17	Other transport equipment	22	2.740	2.555	16	2.010	2.642	15	2.043	2.391
18	Manufacturing nec; recycling	4	2.733	3.307	1	1.916	2.384	21	1.965	1.648
19	Electricity, gas and water supply	15	2.689	3.504	13	1.773	2.757	25	1.937	1.763
20	Construction	13	2.648	3.475	26	1.679	1.283	24	1.834	1.849
21	Wholesale and retail trade; repairs	10	2.641	3.097	24	1.658	1.597	17	1.815	2.416
22	Hotels and restaurants	16	2.563	3.802	18	1.604	2.991	19	1.789	1.423
23	Transport and storage	33	2.477	2.490	3	1.594	2.525	16	1.765	3.120
24	Post and telecommunications	18	2.444	2.391	25	1.568	1.280	18	1.648	2.110
25	Financial intermediation	3	2.434	2.940	4	1.566	2.618	33	1.521	1.734
26	Real estate activities	14	2.359	3.470	17	1.548	2.671	3	1.512	2.574
27	Renting of machinery and equipment	24	2.334	2.017	20	1.385	2.100	4	1.477	2.205
28	Computer and related activities	17	2.057	3.402	33	1.380	1.893	26	1.443	1.483
29	R&D and other business activities	26	1.785	2.062	14	1.348	2.711	20	1.339	2.002
30	Public admin. and defence; compulsory social security	32	1.426	2.703	30	1.191	1.521	22	1.329	1.911
31	Education	31	1.335	2.081	31	1.189	1.477	31	1.162	1.466
32	Health and social work	20	1.058	3.168	22	1.187	1.868	30	1.130	1.894
33	Other community, social and personal services	30	1.045	2.287	32	1.094	1.533	32	1.032	1.704
34	Private households with employed persons	34	1.000	1.000	34	1.000	1.000	34	1.000	1.000
	Correlation			0.369			0.456			0.435
	Unweighted average		**2.760**	**2.783**		**2.068**	**2.231**		**2.003**	**2.031**
	Weighted average		**2.799**	**2.899**		**1.907**	**1.734**		**1.815**	**1.869**

Note: The calculations are based on the TiVA 2016 edition. The first two columns provide the sector index and description. See Table A.2 for more details of the sector classifications. For each country, the sectors are ranked by the upstreamness measure U_{AC}. The correlation statistics provide the correlation between the two measures, U_{AC} and D_{AC}, across sectors. The average statistics refer to the average of each measure across sectors. The weighted average is weighted by the sector output.

Table A.5. GVC position in 2015 by the Measures of Antràs and Chor (2018)

Sector	Description	SINGAPORE			JAPAN			TAIWAN			KOREA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
1	Agriculture, forestry and fishing	23	3.357	2.172	2	3.555	1.853	2	4.356	1.904	2	4.001	2.051
2	Mining and extraction of energy producing products	29	3.308	1.917	13	3.343	2.767	10	3.832	2.975	3	3.682	1.976
3	Mining and quarrying of non-energy producing products	21	3.298	2.455	8	3.207	2.497	3	3.831	1.966	8	3.480	2.725
4	Mining support service activities	10	3.155	2.836	3	3.093	2.356	9	3.580	2.472	10	3.476	2.774
5	Food products, beverages and tobacco	11	3.142	2.492	11	2.896	2.361	13	3.393	3.111	13	3.468	2.868
6	Textiles, wearing apparel, leather and related products	8	3.116	2.355	10	2.722	2.356	4	3.242	1.926	11	3.320	2.781
7	Wood and products of wood and cork	27	3.114	2.348	14	2.687	2.433	21	3.136	2.138	9	3.191	2.657
8	Paper products and printing	31	3.074	2.041	7	2.674	2.295	8	3.114	2.660	4	3.183	1.255
9	Coke and refined petroleum products	9	3.058	2.861	12	2.627	2.191	23	3.010	1.679	14	3.079	2.729
10	Chemicals and pharmaceutical products	24	3.044	2.700	9	2.623	2.555	11	2.941	2.789	21	3.070	2.251
11	Rubber and plastic products	13	3.020	2.990	18	2.551	2.805	15	2.903	2.488	15	3.037	2.787
12	Other non-metallic mineral products	12	2.911	2.774	4	2.504	2.585	12	2.901	2.525	6	2.857	2.839
13	Basic metals	14	2.817	2.629	6	2.474	2.361	29	2.720	1.623	1	2.817	2.020
14	Fabricated metal products	26	2.683	2.709	1	2.376	2.114	7	2.701	2.669	23	2.771	2.061
15	Computer, electronic and optical products	15	2.630	2.689	31	2.337	1.655	24	2.637	2.224	12	2.753	2.653
16	Electrical equipment	19	2.610	2.851	23	2.325	1.675	6	2.624	2.730	7	2.748	2.824
17	Machinery and equipment, nec	28	2.574	2.385	21	2.305	2.246	14	2.523	2.803	16	2.711	2.814
18	Motor vehicles, trailers and semi-trailers	16	2.458	2.636	15	2.203	2.254	31	2.482	1.674	27	2.634	2.414
19	Other transport equipment	30	2.236	1.688	24	2.027	1.808	27	2.304	1.845	24	2.553	2.274
20	Other manufacturing; repair and installation of machinery and equipment	5	2.097	2.530	16	1.959	2.447	16	2.273	2.832	29	2.540	1.953
21	Electricity, gas, water supply, sewerage, waste and remediation services	17	2.063	2.619	29	1.946	1.615	26	1.710	2.120	31	2.519	1.863
22	Construction	1	1.939	2.062	34	1.930	1.785	34	1.687	1.764	5	2.248	2.906

Table A.5. (*Continued*)

Sector	Description	SINGAPORE			JAPAN			TAIWAN			KOREA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
23	Wholesale and retail trade; repair of motor vehicles	20	1.915	2.646	27	1.898	1.995	19	1.663	2.794	17	2.170	2.763
24	Transportation and storage	35	1.896	1.995	17	1.846	2.272	17	1.656	2.895	18	2.087	2.899
25	Accommodation and food services	22	1.757	2.673	5	1.828	2.313	35	1.600	1.881	26	1.990	2.410
26	Publishing, audiovisual and broadcasting activities	6	1.659	2.407	26	1.711	2.320	1	1.591	2.033	28	1.893	2.070
27	Telecommunications	18	1.652	2.391	20	1.631	2.357	20	1.548	2.554	19	1.842	2.907
28	IT and other information services	25	1.534	2.202	19	1.605	2.590	25	1.493	2.006	34	1.700	2.080
29	Financial and insurance activities	7	1.457	2.544	28	1.554	1.653	5	1.461	2.603	20	1.573	2.836
30	Real estate activities	34	1.335	2.009	25	1.320	2.232	28	1.387	1.729	35	1.409	2.161
31	Other business sector services	33	1.314	1.526	35	1.263	1.822	18	1.361	2.788	25	1.334	2.450
32	Public admin. and defence; compulsory social security	32	1.268	2.565	22	1.252	2.205	22	1.117	2.647	30	1.315	1.418
33	Education	36	1.000	1.000	30	1.248	1.366	32	1.107	1.718	33	1.119	1.620
34	Human health and social work	2	..	..	32	1.009	1.624	33	1.070	1.520	32	1.117	1.647
35	Arts, entertainment, recreation and other service activities	3	..	..	33	1.009	1.343	30	1.050	1.387	22	1.050	2.567
36	Private households with employed persons	4	..	..	36	1.000	1.000	36	1.000	1.000	36	1.000	1.000
	Correlation			0.418			0.553			0.284			0.316
	Unweighted average		2.378	2.385		2.126	2.114		2.306	2.235		2.437	2.342
	Weighted average		2.715	2.402		1.982	2.004		2.452	2.241		2.370	2.402

Sector	Description	CHINA			HONG KONG			USA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
1	Agriculture, forestry and fishing	2	4.529	2.263	4	3.330	3.026	4	3.537	1.693
2	Mining and extraction of energy producing products	4	4.248	2.494	9	3.047	2.874	2	3.096	1.385

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Table A.5. (*Continued*)

		CHINA			HONG KONG			USA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
3	Mining and quarrying of non-energy producing products	3	4.048	2.568	13	2.825	3.252	13	3.032	2.504
4	Mining support service activities	9	3.785	2.726	3	2.822	3.084	3	2.980	1.620
5	Food products, beverages and tobacco	8	3.708	2.753	29	2.710	1.729	7	2.555	2.477
6	Textiles, wearing apparel, leather and related products	21	3.565	2.478	21	2.671	2.047	14	2.485	2.288
7	Wood and products of wood and cork	10	3.472	2.896	24	2.613	2.213	8	2.450	2.300
8	Paper products and printing	13	3.367	3.104	31	2.601	2.155	31	2.430	1.676
9	Coke and refined petroleum products	11	3.266	3.133	11	2.501	2.415	12	2.324	2.089
10	Chemicals and pharmaceutical products	29	3.013	1.392	10	2.370	2.567	1	2.315	2.130
11	Rubber and plastic products	31	3.000	2.274	27	2.336	1.879	11	2.303	2.309
12	Other non-metallic mineral products	23	2.914	1.800	12	2.115	2.642	29	2.263	1.726
13	Basic metals	24	2.888	2.220	23	2.002	1.749	9	2.169	2.011
14	Fabricated metal products	6	2.855	2.981	5	1.935	2.474	16	2.150	2.166
15	Computer, electronic and optical products	7	2.839	2.868	6	1.927	2.694	15	2.120	1.535
16	Electrical equipment	14	2.731	3.217	16	1.920	2.582	17	2.107	2.315
17	Machinery and equipment, nec	1	2.650	2.117	28	1.888	1.712	27	2.065	2.046
18	Motor vehicles, trailers and semi-trailers	12	2.640	2.784	2	1.870	3.029	10	2.022	1.969
19	Other transport equipment	15	2.575	3.217	26	1.861	1.974	24	1.991	1.880
20	Other manufacturing; repair and installation of machinery and equipment	27	2.349	1.633	7	1.700	3.367	21	1.952	1.609
21	Electricity, gas, water supply, sewerage, waste and remediation services	16	2.322	3.244	1	1.527	2.337	23	1.829	1.644
22	Construction	25	2.302	2.227	14	1.509	2.741	26	1.795	1.574
23	Wholesale and retail trade; repair of motor vehicles	5	2.034	2.574	8	1.499	2.370	30	1.645	1.446
24	Transportation and storage	28	2.021	2.424	15	1.471	2.744	6	1.593	2.339
25	Accommodation and food services	20	1.965	2.777	35	1.462	1.894	5	1.559	2.455

Table A.5. (*Continued*)

		CHINA			HONG KONG			USA		
		Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}	Sector	U_{AC}	D_{AC}
26	Publishing, audiovisual and broadcasting activities	17	1.932	3.124	22	1.335	2.419	28	1.488	1.621
27	Telecommunications	35	1.853	1.859	20	1.309	2.495	19	1.433	2.238
28	IT and other information services	18	1.717	3.238	19	1.284	2.316	20	1.369	2.112
29	Financial and insurance activities	34	1.654	2.235	34	1.283	1.730	33	1.368	1.424
30	Real estate activities	26	1.653	2.176	18	1.279	2.692	18	1.344	2.664
31	Other business sector services	19	1.637	3.025	33	1.264	1.471	25	1.263	1.893
32	Public admin. and defence; compulsory social security	30	1.450	1.447	17	1.210	3.358	32	1.169	1.690
33	Education	33	1.059	1.774	25	1.156	2.030	35	1.136	1.728
34	Human health and social work	32	1.038	1.939	30	1.139	1.377	34	1.027	1.725
35	Arts, entertainment, recreation and other service activities	22	1.029	2.872	32	1.119	1.686	22	1.024	1.928
36	Private households with employed persons	36	1.000	1.000	36	1.000	1.000	36	1.000	1.000
	Correlation			**0.264**			**0.338**			**0.145**
	Unweighted average		**2.531**	**2.468**		**1.886**	**2.337**		**1.955**	**1.922**
	Weighted average		**2.521**	**2.554**		**1.890**	**2.022**		**1.761**	**1.786**

Note: The calculations are based on the TiVA 2018 edition. The first two columns provide the sector index and description. See Table A.2 for more details of the sector classifications. For each country, the sectors are ranked by the upstreamness measure U_{AC}. The correlation statistics provide the correlation between the two measures, U_{AC} and D_{AC}, across sectors. The average statistics refer to the average of each measure across sectors. The weighted average is weighted by the sector output. The data for sectors 2–4 are not separately available for Singapore.

Table A.6. Position in the GVC (1995–2011) for a Larger Set of Countries

	1995				2000		
	VS	GVC^{BM}	D		VS	GVC^{BM}	D
Japan	5.61%	25.54%	0.22	Brunei	5.35%	29.91%	0.18
Brunei	7.26%	24.09%	0.30	Japan	7.38%	31.12%	0.23
Peru	9.85%	27.89%	0.35	Peru	10.71%	30.51%	0.35
Brazil	7.79%	20.74%	0.38	United States	12.52%	34.30%	0.36
United States	11.43%	29.08%	0.39	Brazil	11.38%	25.48%	0.45
Australia	11.97%	27.00%	0.44	Australia	15.69%	33.43%	0.47
Germany	14.79%	33.07%	0.45	UK	17.93%	36.96%	0.49
Chile	14.11%	30.10%	0.47	Germany	20.08%	39.62%	0.51
UK	18.17%	34.50%	0.53	Chile	21.34%	40.60%	0.53
France	17.15%	32.54%	0.53	Italy	19.88%	35.28%	0.56
Italy	17.16%	30.43%	0.56	France	22.76%	38.97%	0.58
Korea	22.26%	36.63%	0.61	Vietnam	27.15%	42.84%	0.63
Vietnam	21.43%	33.55%	0.64	Korea	29.56%	46.60%	0.63
New Zealand	16.79%	26.33%	0.64	New Zealand	22.09%	34.02%	0.65
Taiwan	30.64%	43.91%	0.70	Taiwan	32.20%	49.32%	0.65
Malaysia	30.40%	43.51%	0.70	Canada	26.80%	36.81%	0.73
Canada	24.15%	34.44%	0.70	Singapore	45.22%	60.02%	0.75
Mexico	27.27%	36.82%	0.74	Malaysia	47.64%	60.52%	0.79
China	30.96%	39.54%	0.78	China	35.89%	45.27%	0.79
Singapore	42.02%	52.57%	0.80	Mexico	34.33%	43.11%	0.80

	2005				2011		
	VS	GVC^{BM}	D		VS	GVC^{BM}	D
Brunei	4.64%	32.16%	0.14	Brunei	4.26%	34.80%	0.12
Japan	11.07%	36.32%	0.30	Peru	11.79%	38.97%	0.30
Peru	12.31%	35.42%	0.35	Brazil	10.71%	29.90%	0.36
Australia	11.97%	32.04%	0.37	Japan	14.66%	40.47&	0.36
United States	12.99%	34.41%	0.38	Australia	13.90%	36.24%	0.38
Brazil	11.69%	27.03%	0.43	United States	14.95%	35.75%	0.42
Chile	18.72%	41.73%	0.45	Chile	19.98%	44.75%	0.45
UK	17.00%	36.74%	0.46	UK	22.88%	42.83%	0.53
Germany	21.26%	41.44%	0.51	New Zealand	16.76%	30.18%	0.56
New Zealand	15.67%	27.70%	0.57	Germany	25.57%	45.91%	0.56
Italy	21.98%	38.59%	0.57	France	25.01%	42.51%	0.59
France	23.38%	40.40%	0.58	Canada	23.55%	38.77%	0.61
Korea	32.91%	52.76%	0.62	Italy	26.37%	43.33%	0.61
Taiwan	37.33%	59.07%	0.63	Taiwan	43.42%	62.71%	0.69
Vietnam	30.93%	45.27%	0.68	China	32.04%	45.82%	0.70
Canada	23.39%	33.87%	0.69	Korea	41.59%	58.00%	0.72
Singapore	39.66%	56.00%	0.71	Mexico	31.65%	44.02%	0.72
China	37.31%	48.93%	0.76	Malaysia	40.51%	56.17%	0.72
Malaysia	45.85%	58.86%	0.78	Singapore	41.59%	57.26%	0.73
Mexico	32.98%	41.63%	0.79	Vietnam	36.33%	48.70%	0.75

Note: The measures are defined in Equation (5) for *VS*, and Equation (4) for *GVC^{BM}*. Downstreamness (*D*) is defined by *VS/GVC^{BM}* as in Equation (7).

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